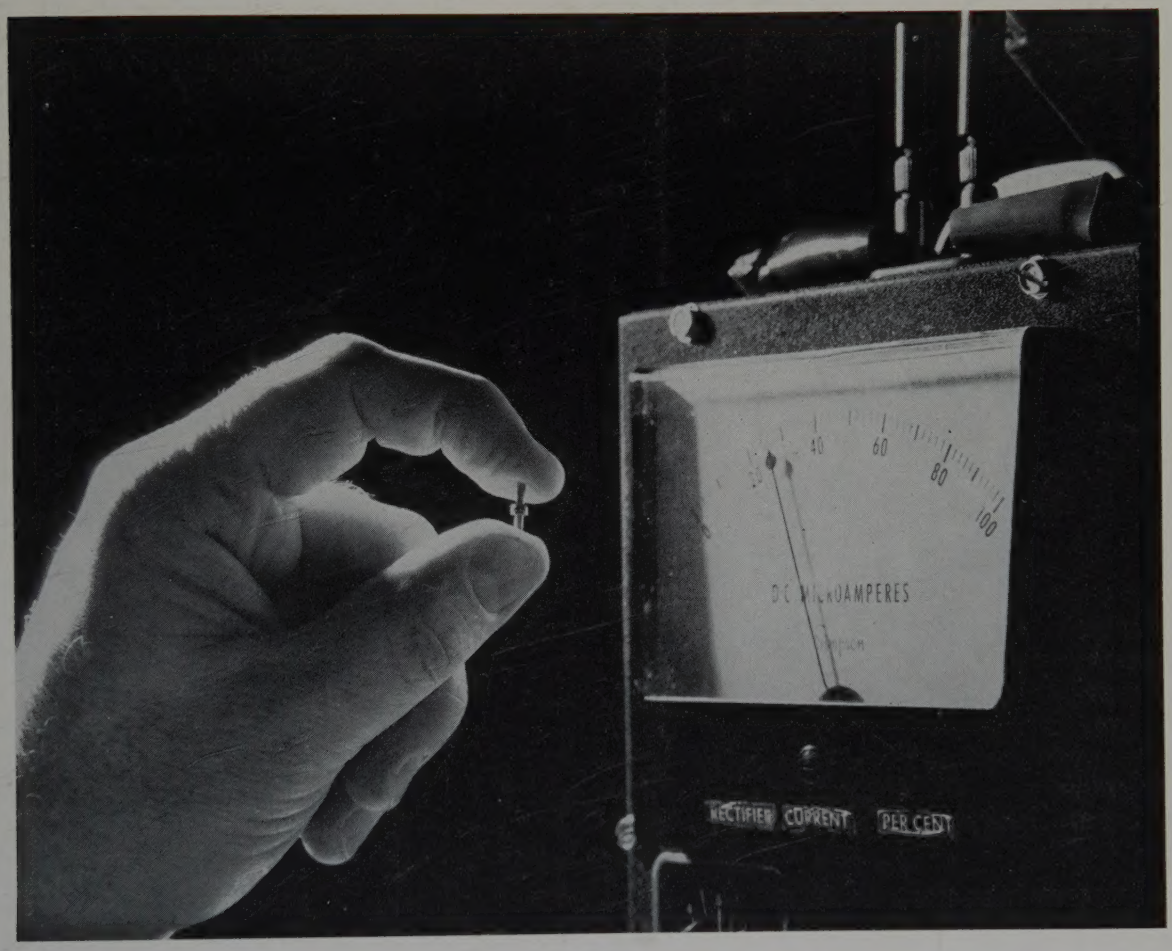
August 1961

75¢

SEMICONDUCTOR PRODUCTS

R&D • DESIGN • TECHNOLOGY • APPLICATIONS



Silicon Disc Fast—Neutron Dosimeter

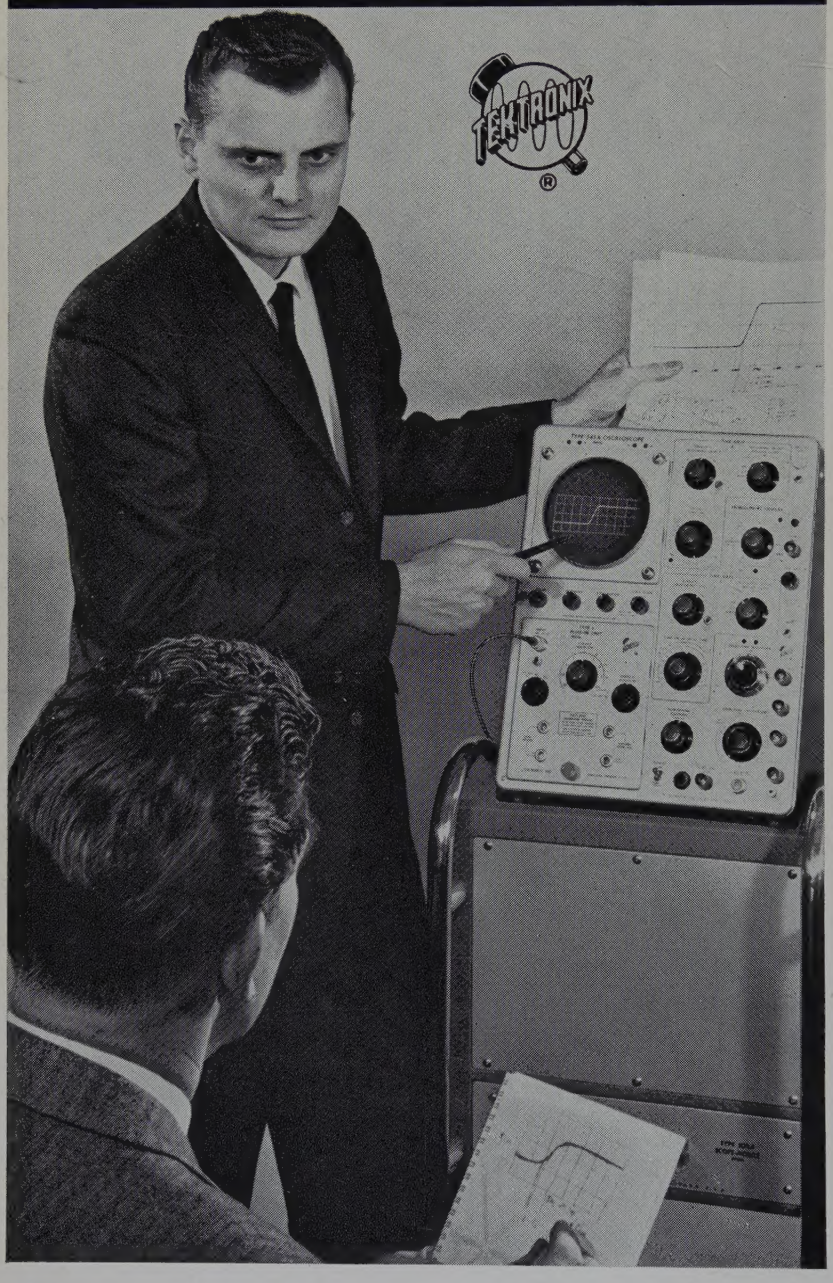
Monostable Circuit for Frequency Division and Short Pulse Generation

Transistor Pulse Amplifiers

Gold Alloying to Eutectic Surfaces

You get Continuing Assistance

WITH YOUR TEKTRONIX EQUIPMENT



Last year, Tektronix Field Engineers traveled nearly 1,000,000 miles to call upon over 25,000 precision-measurement-minded people—whom they talked with personally. Most of these people owned Tektronix equipment. Most of these calls concerned continuing assistance—**1** *in seeking additional training in oscilloscope theory;* **2** *in learning simplified techniques for present applications;* **3** *in planning new applications for present equipment;* **4** *in installing factory modifications in older instruments;* **5** *in ordering additional equipment for their laboratory.*

This personal touch in providing continuing assistance to users of Tektronix equipment characterizes the Field Engineer.

In 34 Field Offices thruout the United States and Canada, he is ready and anxious to help you with any phase of activity involving precision measurement. Trained in all facets of the oscilloscope art, your Field Engineer can be your best source of help—*before, during* and *after* the delivery of your Tektronix instruments.

20 TEKTRONIX REPAIR CENTERS FOR INSTRUMENT MAINTENANCE

Your Field Engineer provides continuing assistance in helping you maintain your Tektronix oscilloscopes and auxiliary equipment to the fullest degree of their capabilities.

For example, when you send your instruments to Tektronix on a periodic maintenance program—as many companies do—your Field Engineer schedules the work thru one of 20 Tektronix Repair Centers.

At these fully-equipped facilities, located thruout the United States and Canada, experienced Tektronix Field Maintenance Engineers perform precisely the instrument-maintenance work requested.

Or, perhaps your own instrument-maintenance technicians handle test and calibration of your Tektronix equipment. For them your Field Engineer will willingly conduct classes in preventive-maintenance procedures. These informal classes covering time-saving, trouble-shooting techniques can be held at your convenience—at a Tektronix Field Office when feasible or at your own company location.

Regardless of your instrument-maintenance need, call your Tektronix Field Engineer. He expects to hear from you . . . for your selection of Tektronix instruments *entitles* you to continuing assistance in maintaining those instruments to their fullest capabilities.

REPAIR AND CALIBRATION

INSTRUMENT MODIFICATION

Two of many instrument-maintenance services available at Tektronix Repair Centers.

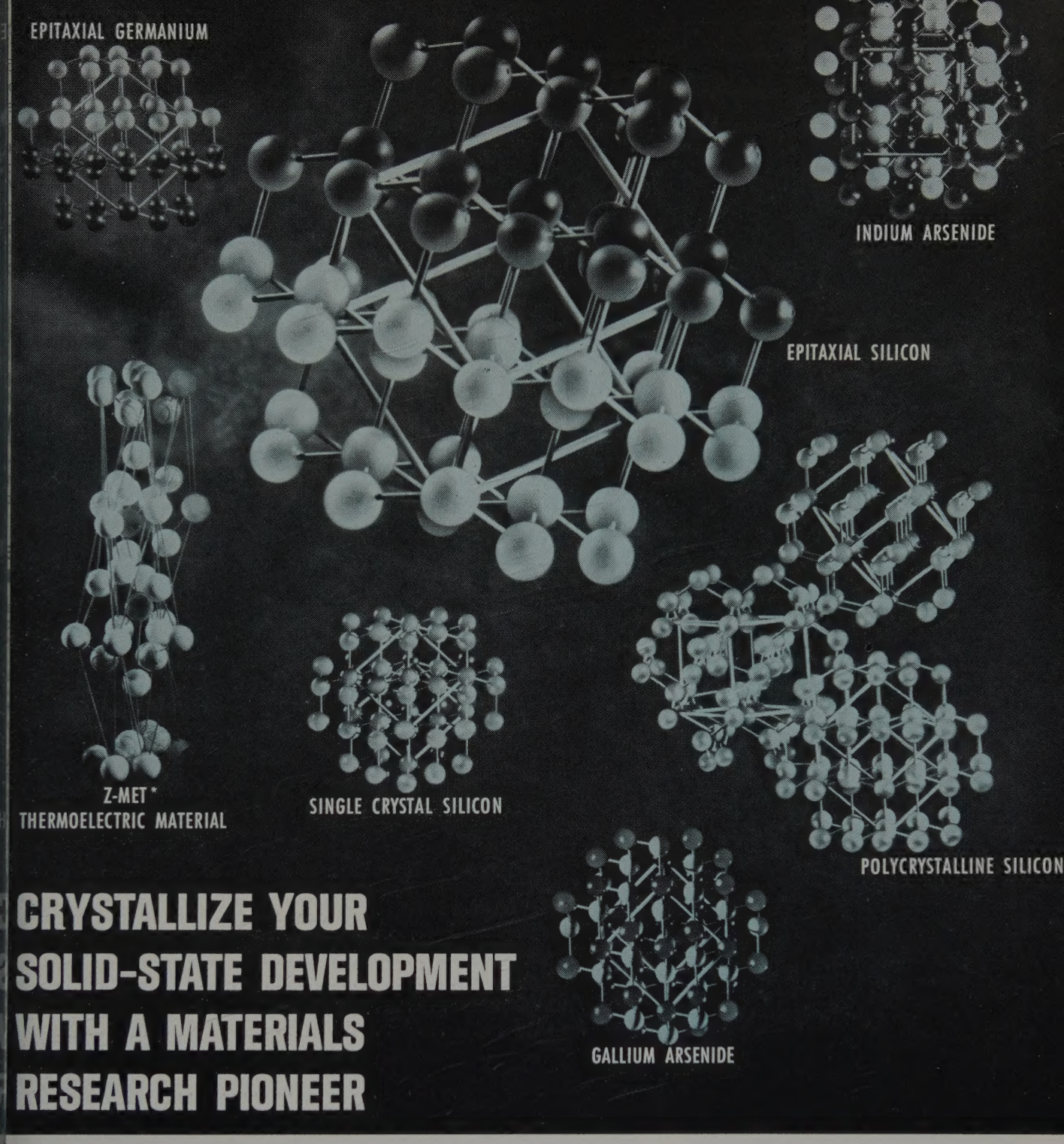
Tektronix, Inc. *P. O. BOX 500 · BEAVERTON, OREGON / Mitchell 4-0161 · TWX–BEAV 311 · Cable: TEKTRONIX*

TEKTRONIX FIELD OFFICES: Albuquerque, N. Mex. • Atlanta, Ga. • Baltimore (Towson) Md. • Boston (Lexington) Mass. • Buffalo, N.Y. • Chicago (Park Ridge) Ill. • Cleveland, Ohio • Dallas, Texas • Dayton, Ohio Denver, Colo. • Detroit (Lathrup Village) Mich. • Endicott (Endwell) N.Y. • Greensboro, N.C. • Houston, Texas • Indianapolis, Ind. • Kansas City (Mission) Kan. • Los Angeles, Calif. Area (East Los Angeles, Encino • West Los Angeles) • Minneapolis, Minn. • Montreal, Quebec, Canada • New York City Area (Albertson, L.I., N.Y. • Stamford, Conn. • Union, N.J.) • Orlando, Fla. • Philadelphia, Pa. • Phoenix (Scottsdale) Ariz. Poughkeepsie, N.Y. • San Diego, Calif. • San Francisco, Calif. Area (Lafayette, Palo Alto) • St. Petersburg, Fla. • Syracuse, N.Y. • Toronto (Willowdale) Ont., Canada • Washington, D.C. (Annandale, Va.).

TEKTRONIX ENGINEERING REPRESENTATIVES: Hawthorne Electronics: Portland, Oregon; Seattle, Washington • Kentron Hawaii Ltd., Honolulu, Hawaii. Tektronix is represented in twenty overseas countries by qualified engineering organizations.

In Europe please contact Tektronix International A.G., Terrassenweg 1A, Zug, Switzerland, Phone (042) 4-91-92, for the address of the Tektronix Representative in your country.

Circle No. 1 on Reader Service Card



CRYSTALLIZE YOUR SOLID-STATE DEVELOPMENT WITH A MATERIALS RESEARCH PIONEER

Your profits in the next decade will be greatly benefited by the right choice of supplier of solid-state materials.

The key question is what criteria to use in making the choice. The simplest, most reliable criterion has to be PAST PERFORMANCE.

Judged on this basis the Electronic Chemicals Division of Merck & Co., Inc. deserves your attention. In just four short years, it has achieved these exclusive major breakthroughs:

1958 Float zone, vacuum refined, doped single crystal silicon · 1959 Z-Met*Thermoelectric materials 1960 Epitaxial silicon N+ N wafers and III-V Compounds · 1961 Epitaxial germanium P+ P wafers

When you hitch your product development to Merck materials research you are enlisting a proved producer. If you want to be the first to exploit new solid-state materials breakthroughs, join the ranks of Merck customers today. Write, wire or phone your needs, problems, hopes.

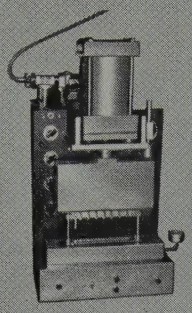
*Trademark

Electronic Chemicals Division
MERCK & CO., Inc. · RAHWAY, NEW JERSEY

RESEARCH and PRODUCTION FOR BETTER SOLID-STATE MATERIALS

Circle No. 5 on Reader Service Card

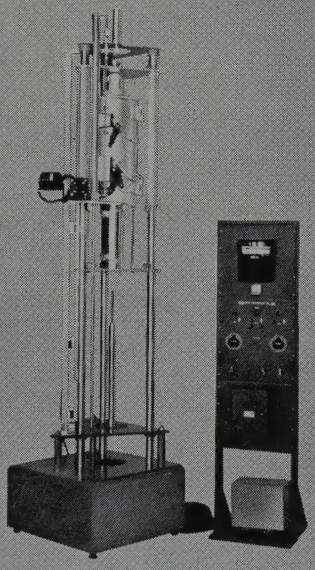
SILICON DIODE SEALER



17" wide — 31" high

7 heads • Inert gas purge • Up to 200 lbs. inert gas pressure under bell

PRODUCTS OF RESEARCH



9' high — 2½' furnace face

Large batch capacity, approaching capacities of conveyor furnaces • requires minimum floor space • 3-zone furnace, reactor controlled • Can be set up for program control

RESEARCH INSTRUMENT COMPANY, INC.

SPECIALISTS IN SEMICONDUCTOR SMALL PARTS, PRODUCTION MACHINERY, DESIGNS TO SPECIFICATION.

Base Tabs • Cans • Microstampings
Swiss automatic products

558 Main Street, Westbury, N.Y.
EDgewood 3-7440

Circle No. 6 on Reader Service Card

SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

August 1961 Vol. 4 No. 8

CONTENTS

Editorial 21

Transistor Pulse Amplifiers, *by V. G. K. Reddi* 23
A Monostable Transistor Circuit For High Ratio Frequency Division and Generation of Short Pulses, (Part I), *by Werner Steiger* 30
Gold Alloying to Germanium, Silicon and Aluminum-Silicon Eutectic Surfaces, (Part II), *by L. Bernstein* 35
Patent Review 42
Semiconductor and Solid State Bibliography 44
Characteristics Charts of New Diodes and Rectifiers 49

Departments
Industry News 8
Market News 18
New Products 57
Book Reviews 68
New Literature 70
Personnel Notes 72

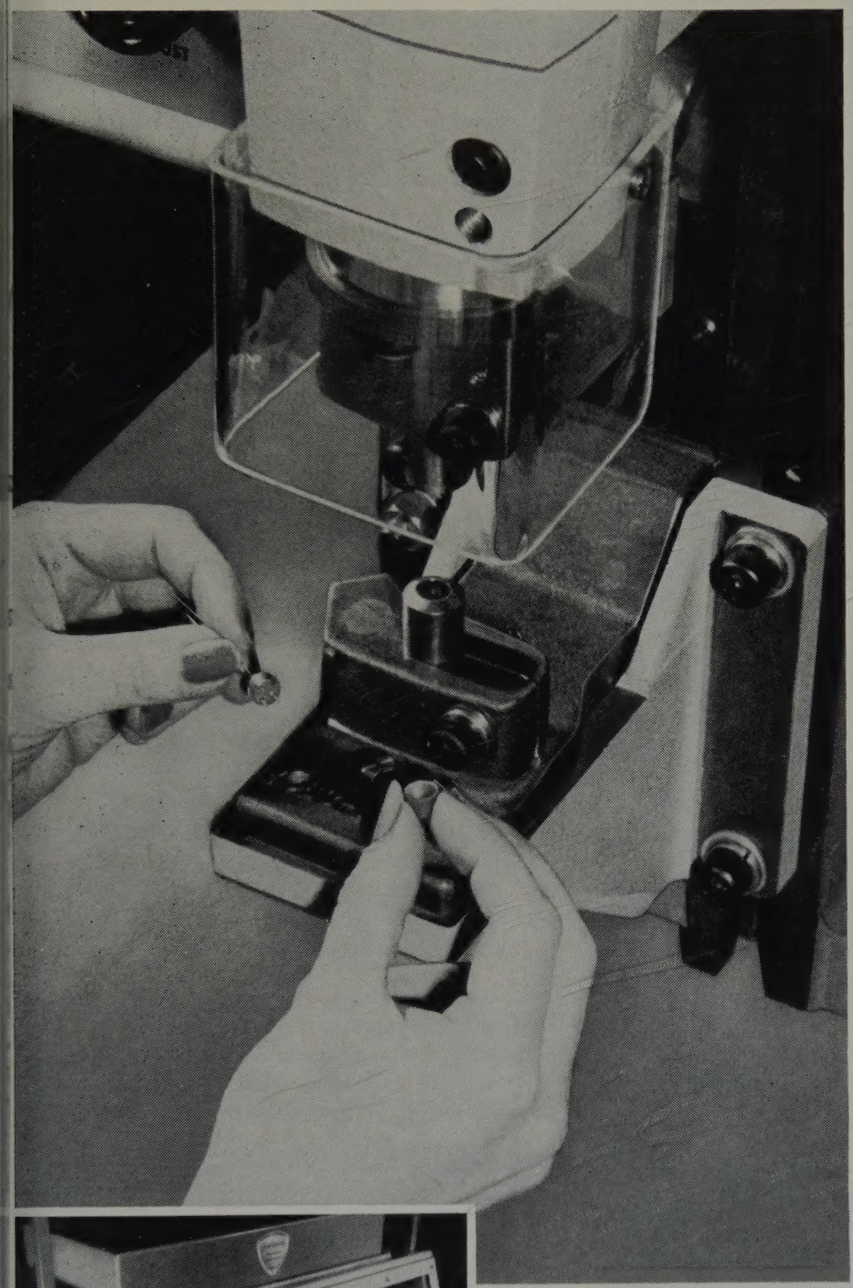
Advertisers' Index 74

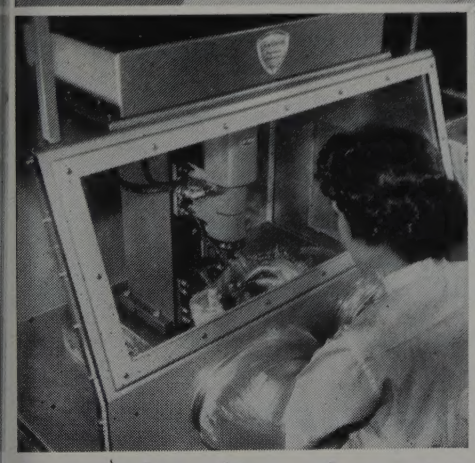
SEMICONDUCTOR PRODUCTS assumes no responsibility for company credit affiliations claimed by authors for byline purposes.

Front Cover

Miniaturized Fast-Neutron Dosimeter, no larger than a carpet tack, consists of an 0.1 by 0.03-inch silicon disc mounted between two electrical contact pins. This device records fast neutron dosage cumulatively, is insensitive to all other forms of radiation, and permits dosage to be measured quickly and easily. Fast neutrons passing through the dosimeter knock some of the silicon atoms from their normal positions, permanently changing the electrical properties of the silicon. This change in electrical properties is to be measured in terms of "tissue rads," units of radiation damage to human tissue. The dosimeter, called a Radiac Detector, is being developed by Battelle Memorial Institute for the U. S. Army Signal Corps. It is designed for use by persons who work around nuclear reactors or who may be exposed to nuclear weapon explosions or other fast-neutron sources.

FOR PRECISION WELDING OF TRANSISTORS AND COMPONENTS





RAYTHEON'S MODEL "M" WELDING HEAD

Newest development in precision welding of miniature parts.

The "M" head—Raytheon's completely new precision welding device—assures consistent welding performance even when joining miniature parts. The secret is the advanced design that achieves relatively low welding currents and electrode pressures.

The new head has extremely fast action and a new low-impact anti-hammer arrangement that extends electrode life many times. It has an air chamber that provides for a deflection of less than .003 inch under full pressure.

The "M" head—thoroughly tested in transistor production—can be mounted horizontally or vertically and is adaptable to dial feed or in-line feed for automated production.

THE UNIQUE ADVANTAGES of an "M" head installation will be obvious to you after reading the latest technical bulletins. Write for them today to Raytheon Company, Commercial Apparatus & Systems Division, Production Equipment Department, 225 Crescent Street, Waltham 54, Massachusetts. In Canada, Raytheon Canada, Waterloo, Ontario.

FEATURES

- Can be used with any welder
- Horizontal or vertical operation
- Adaptable to dry box installations
- Quick, easy servicing, electrode changing
- Adjustable linear bushing and electrode alignment
- Long electrode life
- Minimum deflection

RAYTHEON

RAYTHEON COMPANY

COMMERCIAL APPARATUS & SYSTEMS DIVISION

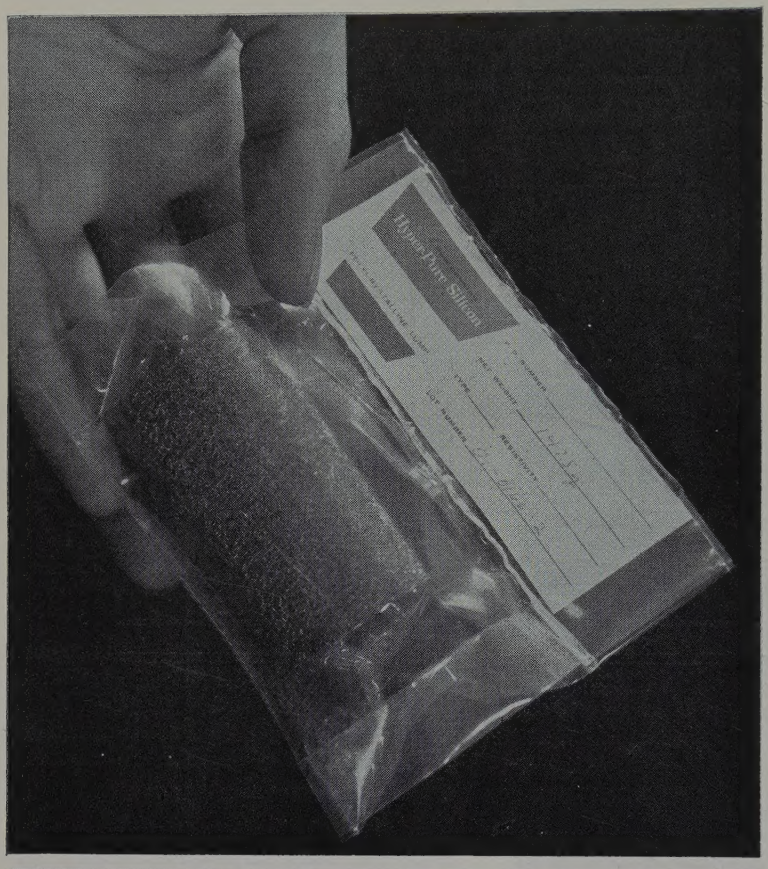
A complete line of precision welding equipment for the electronics industry

Circle No. 7 on Reader Service Card

(Part 4)

The Untouchables

Specify Crucible Charges of Deposited Hyper-Pure Silicon



Pre-packaged single piece crucible charges . . . in sizes and weights to meet the exact requirements of your Czochralski crystal growing equipment . . . are now available from Dow Corning.

Accurately Pre-weighed, these single piece crucible charges assure easy handling . . . smallest surface area . . . highest purity . . . an exceptionally clean melt and a savings in crucible costs.

High Quality is inherent in Dow Corning crucible charges. The *deposited* polycrystalline silicon in these charges has never touched a mold. Result — highest purity.

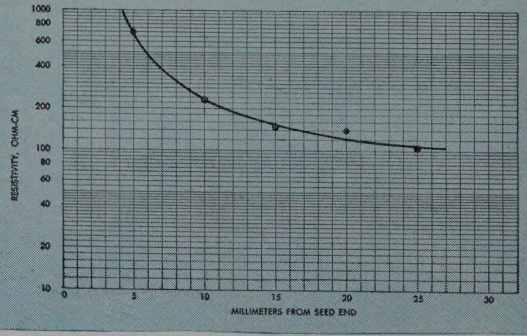
This High Purity means consistently higher quality crystals — simplifies doping procedures — increases device yield. Typical resistivity of N-type crystals grown from Dow Corning prepackaged crucible charges is greater than 100-ohms centimeter for 80% of the crystal; maximum boron content, 0.3 parts per billion atoms; maximum donor impurity, 2.0 parts per billion.

Now You Specify the Weight and Diameter, up to 38 mm (about 1½″), best suited for each crucible of your Czochralski crystal growing machines. Your crucible charges will be supplied in the appropriate length to provide the exact weight you require in just one piece.

Protective Packaging guards initial *deposited* purity right through crucible charging. Charges are individually wrapped in special cellophane, and sealed in airtight polyethylene envelopes to assure untouchable purity.

Whatever your need — deposited silicon crucible charges; polycrystalline rod or chunk; high resistivity P-type single crystal rod; single crystal rod doped to your specifications — Dow Corning should lead your list of sources.

Profile of Crystal Grown from Pre-Packaged Charge



Free brochure — "Hyper-Pure Silicon for Semiconductor Devices." Write Dept. 1820.

HYPER-PURE SILICON DIVISION
Address: HEMLOCK, MICHIGAN

VISIT OUR BOOTH 5102-06, AT WESCON SHOW

Dow Corning CORPORATION
MIDLAND, MICHIGAN
ATLANTA BOSTON CHICAGO CLEVELAND DALLAS LOS ANGELES NEW YORK WASHINGTON, D.C.

Circle No. 8 on Reader Service Card

Semiconductor Products

EDITOR
Samuel L. Marshall

ASSOCIATE EDITOR
Oscar Fisch

ASSISTANT EDITOR
Selma Uslaner

ADVISORY EDITORS
Dr. Lucio M. Vallese
Hugh R. Lowry
C. D. Simmons
Arthur H. Seidman

CONTRIBUTING EDITORS
Henry E. Marrows
Stephen E. Lipsky

PRODUCTION MANAGER
Cary L. Cowan

ART EDITOR
Michael A. Dominguez

CONTROLLER
H. Turok

ADVERTISING SALES

Richard A. Cowan
National Advertising Director

Jack N. Schneider
Advertising Manager

300 West 43rd Street
New York, 36, N. Y.
JUdson 2-4460

CIRCULATION

Harold Weisner
Circulation Director

Clinton Ide
Circulation Mgr.

SEMICONDUCTOR PRODUCTS is published monthly by Cowan Publishing Corp., Executive and Editorial Offices: 300 West 43rd Street, New York 36, N. Y. Telephone JUdson 2-4460. Known office of Publication 50 Emmett Street, Bristol, Connecticut. Subscription price $6.00 for 12 issues in the United States, U.S. Possessions, APO & FPO, Canada and Mexico. All other countries $10.00 for 12 issues. Single copy 75¢. Direct all correspondence to N. Y. office. Second Class Postage Paid at Bristol, Connecticut.

Copyright 1961 by Cowan Publishing Corp.

POSTMASTER: SEND FORM 3579 to SEMICONDUCTOR PRODUCTS, 300 West 43rd STREET, NEW YORK 36, N. Y.

One of many assembly lines of skilled operators employing AO CYCLOPTIC Stereoscopic Microscopes to assemble advanced germanium computer transistors at Texas Instruments vast Semiconductor —Components division in Dallas, Texas.

Here's how Texas Instruments mass produces precision transistors

with AO's CYCLOPTIC Microscope

Precision assembly of minute components for transistor production offers no problem to the skilled workers at Texas Instruments. Using the AO CYCLOPTIC Stereoscopic Microscope, material that is practically invisible to the eye assumes accurately magnified proportions... the entire assembly operation is observed in crisp, erect, three-dimensional detail.

Bright, shadowless lighting is beamed deep inside the small unit apertures with AO's exclusive Vertical Illuminator attachment. The instrument's remarkable long working distance assures the operator of complete freedom of movement and affords ample room to accommodate larger objects and assembly tools.

With the instrument body inclined at a 30° angle, the operator can work in a natural, more comfortable position.

When manufacturing small precision assemblies... many progressive companies such as TI, depend upon the AO CYCLOPTIC to render the unit in visual "working size" dimensions.

If you have a particular production situation that 3-D magnification would help, why not discuss it with a capable AO Sales Representative. He can recommend the AO CYCLOPTIC Stereoscopic Microscope that will certainly solve your individual problem. There is no obligation, of course.

American Optical COMPANY
INSTRUMENT DIVISION, BUFFALO 15, NEW YORK

Dept. V266
☐ Please have AO Sales Representative demonstrate the AO CYCLOPTIC Microscope.
☐ Please send AO CYCLOPTIC Brochure SB56.

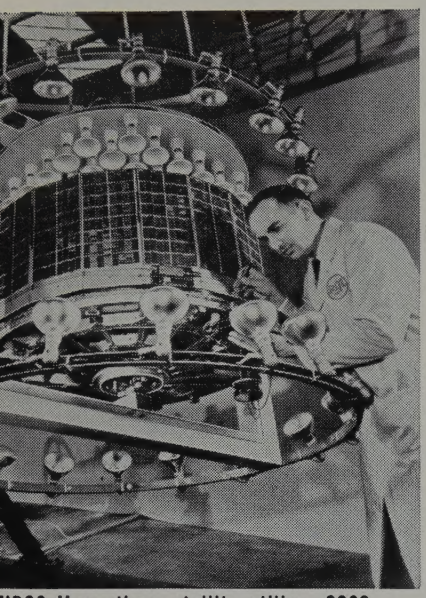
NAME_____
ADDRESS_____
CITY_____ ZONE____ STATE_____

IN CANADA write — American Optical Company Canada Ltd., Box 40, Terminal A, Toronto, Ontario

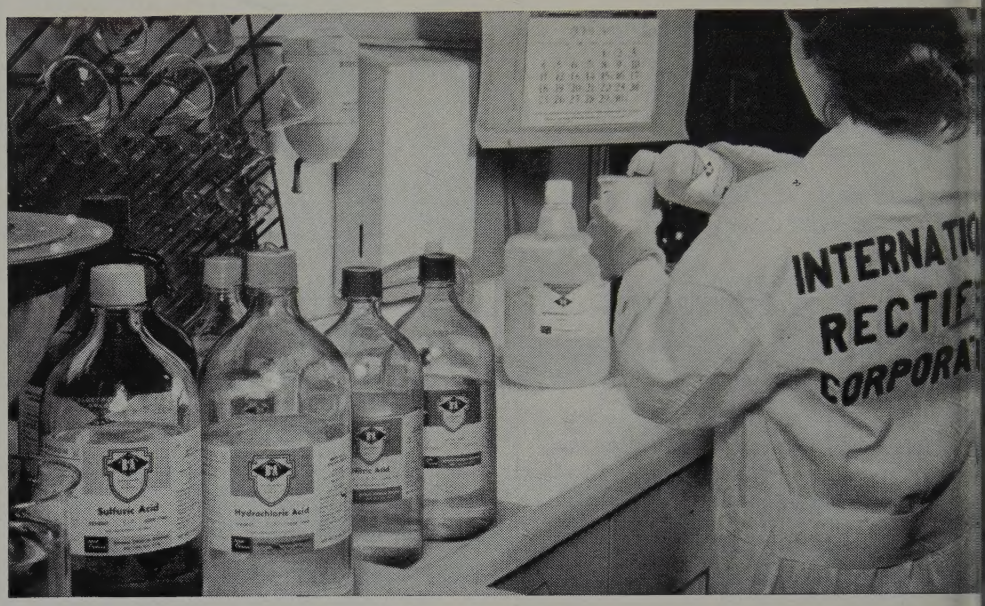
Circle No. 9 on Reader Service Card

Why INTERNATIONAL RECTIFIER CORP. relies on B&A electronic chemicals

Ultra-high purity B&A® "Electronic Grade" chemicals help maintain process uniformity; increase efficiency of devices that convert light into electrical energy.



TIROS II weather satellite utilizes 9260 International Rectifier silicon solar cells for auxiliary power (Photo courtesy of RCA). International Rectifier silicon readout cells are widely used in computers; photocells in automatic exposure "electric eye" cameras.



In addition to being a major supplier of semiconductor diodes and rectifiers, International Rectifier Corporation has been a pioneer and leader in the development and production of photoelectric cells and silicon solar cells for applications ranging from satellites to computers to cameras.

The high efficiency and reliability of photovoltaic devices depend upon technology, infinite care and immaculate processing. In the processing phase, where high purity and uniformity in chemicals is a critical need, International Rectifier relies on B&A "Electronic Grade" chemicals.

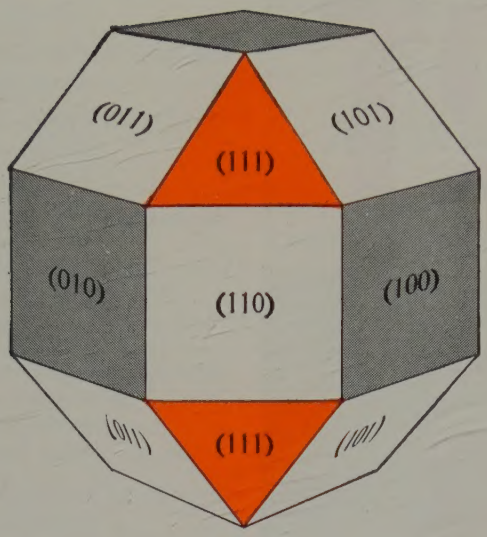
If chemical purity and reliability affect the quality of *your* products, you ought to know the full B&A quality story. A request on your company letterhead will bring detailed information.

BAKER & ADAMSON®
"Electronic Grade" Chemicals

Allied Chemical

GENERAL CHEMICAL DIVISION
40 Rector Street, New York 6, N.Y.

Circle No. 10 on Reader Service Card



Semimetals Adds One More...CUSTOMER ORIENTATION

When sudden demands strain your crystal growing department, turn to Semimetals for monocrystal germanium. We understand the needs of device manufacturers...the schedule peaks that must be levelled...the requirements for delivery on a crash basis...the unusual material in lab quantities for experimentation...the technical assistance on special problems. We also understand the necessity of protecting your proprietary information...keeping it in strictest confidence. These are the results of our total customer-orientation; our knowledgeability in the business.

For many years, we have been a prime germanium crystal source to the semiconductor industry. We produce monocrystals by both zone levelling and Czochralski techniques, in standard orientations, with dopants as specified. Etch-pit concentrations of 2,000 to 5,000/cm², 4,000 to 8,000/cm² and 6,000 to 12,000/cm² are supplied as standard; lower dislocation densities can be produced on special request. Low-lifetime materials for fast-switching applications are available.

Semimetals is also an excellent source for infrared device materials. Whether your needs are cast germanium, single-crystal germanium, or silicon, investigate our facilities.

SEMIMETALS, INC. 172 Spruce Street • Westbury, L. I., N. Y. • EDgewood 3-8400

Circle No. 11 on Reader Service Card

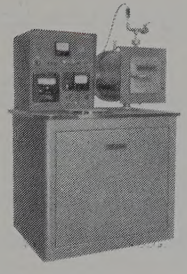
TRI METAL

VACUUM OVENS

1ST

FIRST TO OFFER

- up to 500°C on your product at 10^{-6} Torr (mmHg)
- no heat transfer to dry box enclosures
- heat-reflective shields for insulation
- temperature uniformity within ± 2°C
- water-cooled outer shell
- low-cost neoprene gaskets with high temperature oven
- ½" thin non-insulated space-saver door
- controlled temperatures up to 800°C
- 6 thermocouple feedthroughs for internal temperature studies as standard equipment
- nichrome or quartz elements optional



Model 0-8 Vacuum Oven with controls and high vacuum gauge mounted on standard TRI METAL high vacuum pumping system "packaged" in metal cabinet with Formica top.

TRI METAL

For a Free Detailed Brochure Write To:
TRI METAL WORKS INC., Industrial Division
1600 Bannard Street, East Riverton,
New Jersey, or Phone 829-2000.

TRI METAL WORKS INC.

HIGH VACUUM SPECIALISTS SINCE 1946

See us in Booth #5117 WESCON Show, Cow Palace San Francisco, Aug. 22-25

A PARTIAL LIST OF CLIENTS: RCA/Western Electric Co. Tullahoma Air Force Base/General Electric Co./Clevite Corp. Union Carbide-Nuclear Div.—Oak Ridge/Burroughs Corp. Princeton University/University of Virginia/F.J. Stokes Corp. H.W. Butterworth—Div. of Van Norman Industries/Drever Co.

Circle No. 12 on Reader Service Card

Industry News . . .

CONFERENCE CALENDAR

The Following September 1961 Meetings Are Scheduled:

Sept 3-8 National Meeting, American Chemical Society, Chicago.

Sept 12-14 Fall Conference, EIA, Biltmore Hotel, New York City

Sept 14-15 Engineering Management Conference, Hotel Roosevelt, New York City. Sponsored by ASME & AIEE

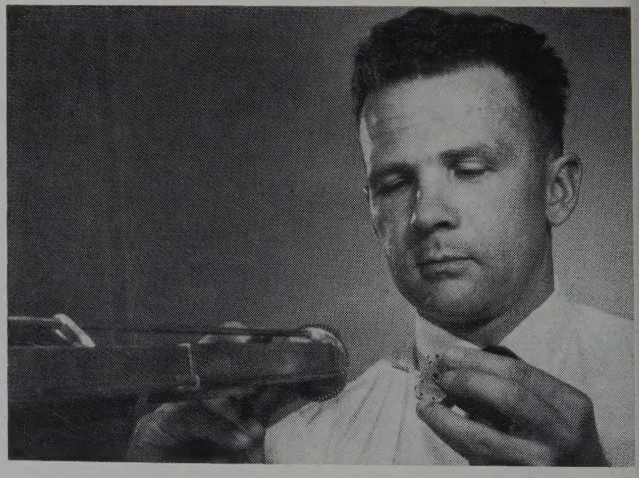
Sept 20-21 Industrial Eectronics Symposium, Bradford Hotel, Boston, Mass. Sponsored by PGIE of IRE, AIEE, ISA. For Information: D. J. La Cerda, Badger Mfg. Co., 363 Third St., Cambridge, Mass.

Sept 25-28 American Welding Society Fall Meeting, Adolphus Hotel, Dallas, Tex. For Information: Information Center, AWS, 33 W. 39th Street, New York 18, N. Y.

Sept 26-30 Instrument & Automation Conference, ISA, Coliseum, NYC.

RESEARCH & DEVELOPMENT

Direct amplification of sound waves using microwave radio energy as a power source has been demonstrated by Dr. Edmund B. Tucker of the General Electric Research Laboratory. Amplification of the sound waves, called phonons, is accomplished by "stimulated emissions" of energy by atoms as they change from a higher to a lower energy level. This is the same mechanism used in the Maser to amplify electromagnetic radiation and the new phenomenon has been termed the phonon Maser effect. According to Dr. Guy Suits, vice president and director of research, this is the first time that stimulated emission has been successfully used to amplify energy other than electromagnetic energy. Dr. Suits noted that, although no immediate commercial application of the



Dr. Edmund B. Tucker inserts ruby rod into apparatus used to measure interaction between sound waves and electromagnetic radiation.

phenomenon is in sight, it provides a significant extension of the principle of stimulated emission, and represents an advance in understanding of the physics of the solid state. The technique may also provide a valuable research tool permitting experimental study of the role of phonons in many physical phenomena. For example, it may make possible an acoustic oscillator for generating sound waves of higher frequency than are now attainable.

A technique for evaluating long range transistor reliability and failure rate with much greater accuracy has been developed by Motorola's Semiconductor Products Division. The technique involves the application of the Weibull distribution function to the analysis of multivariate life test results on transistors. According to A. A. Procassini, Manager of Semiconductor Reliability and Quality Control, the commonly used Constant Failure Rate concept of semiconductor life does not result in an accurate and comprehensive prediction of transistor failures. Matrix tests involving 27 different operating life test conditions over a period of millions of unit hours have shown that transistor failure rate is not constant, as previously supposed, but varies with time in such a way that it fits the Weibull distribution. The application of this theory paves the way for a more accurate evaluation of transistor reliability data and results in a high degree of confidence with a substantial reduction in sample sizes. The Weibull function is a statistical method for evaluating distributions of data as a function of time. Motorola's technique in applying the Weibull distribution results in an expression for the cumulative percent failures, at any given time, for any combination of ambient temperature, power dissipation and voltage.

The Stirling engine, invented 145 years ago but eclipsed by the internal combustion engine, may gain a new importance in the current drive for new power sources and energy conversion devices. This is the prediction of a technologist at Battelle Memorial Institute, Columbus, Ohio. Writing in the current (May) issue of the *Battelle Technical Review*, Dr. Theodor Finkelstein observes that regenerative thermal machines are now "under intensive study for applications as diverse as outboard motor and infrared cell coolers, air conditioners and irrigation pumps." Renewed interest in regenerative thermal machines, of which the Stirling engine is the best known, is closely related to the search for suitable power converters using solar and nuclear sources. "In these new technological areas, regenerative cycles have considerable potential," according to Dr. Finkelstein. Stated another way, these sources of energy may make it possible to avoid material and design limitations inherent in this type of machine when coal or oil are used to supply heat for the engine.

Stirling or regenerative type engines have often been described as "external combustion" engines, as opposed to internal combustion engines of the type used in automobiles. This description, Dr. Finkelstein notes, sums up the drawbacks that have caused the Stirling engine to be considered more a historic curiosity than a practical device in recent times. The main difficulty with regenerative machines, when fossil fuel is used to provide heat, is the necessity to transfer heat from the outside of an enclosure, such as a cylinder wall, to the inside. The creep strength of engineering materials at elevated temperature thus limits the temperature and pressure which can be used. Output is also restricted by the area available for heat transfer and by the unavoidable temperature differential between the outside and the inside.

REDUCE COSTLY KERF LOSSES

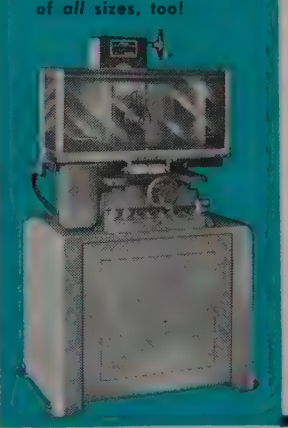
in slicing semiconductor material...

Now . . . switch to 3½" diameter diamond wheels to slice 1" diameter crystals on

Micromech **WAFERING MACHINES**

featuring the ***NEW*** **TYPE 2 CARTRIDGE SPINDLE**

Micromech's newly-designed Type 2 Cartridge Spindle permits the use of thinner, smaller-diameter diamond wheels for slicing germanium and silicon. Provides top wafering efficiency with wheels of *all* sizes, too!



This specially-engineered spindle mounts a 3½" diamond wheel in place of the usual 5" wheel to give from 40% to 100% more slices per 1" diam. crystal . . . reduce kerf loss by 28% to 47%!

Micromech's thinner blades in 3½" diameter size can save from .004" to .009" per slice . . . add up to savings of $200.00 a day!

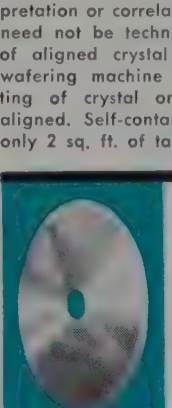
Moreover, the 3½" wheel allows cutting speeds up to 3" per minute . . . increasing production while decreasing loss of material.

Type 2 Cartridge Spindle is now standard on Micromech hydraulic automatic wafering machines. Write today for detailed information.

FOR QUALITY CONTROL —

Micromech Optical Orientation System

This easy-to-operate system produces accurate visual patterns for identification of principal planes of any single crystal material. No interpretation or correlation data needed. Operator need not be technically trained. Transference of aligned crystal from orientation base to wafering machine table allows accurate cutting of crystal on plane to which it was aligned. Self-contained low-cost unit requires only 2 sq. ft. of table space.



Micromech Diamond Wheels

Micromech stocks 3½" diamond wheels for the economical and fast slicing of all semiconductor materials.

Wheels also available in other popular and odd sizes, DIT and DITRS types. Precision manufacture to close tolerances assures accuracy of cut and long life.

Send for free technical data

MICROMECH MANUFACTURING CORP.

A Division of Sanford Manufacturing Corp.

695 Rahway Avenue Union, New Jersey MUrdock 7-3200

Circle No. 13 on Reader Service Card

How HEWLETT-PACKARD uses Lindberg Diffusion Furnaces for production of silicon diodes

QUOTE from Mr. Ray Morris

Ray Morris, Process Engineer, and Lindberg Diffusio. Furnaces at Hewlett-Packard Co., Palo Alto, Calif.

"Precision Components Division, Hewlett-Packard, manufactures diffused silicon diodes for HP electronic measuring instruments. Precise targeting of diode characteristics for specific instruments imposes severe limitations upon the diffusion operation. The Lindberg Diffusion Furnaces which we recently installed are meeting these exacting requirements satisfactorily. They are actually exceeding uniformity guarantees and are providing a consistently reproducible temperature profile."

The Lindberg furnaces serving so satisfactorily at Hewlett-Packard are from Lindberg's complete line of equipment for production of semiconductors, solid state and other electronic devices. Processes covered by this equipment include gaseous and solid diffusion, germanium reduction, crystal growing, zone refining, bonding, and special processes with controlled atmospheres or vacuum. These units are precision-designed for precision results and dependable production performance. Lindberg also makes available to you the technical capabilities of our experienced research and design staff to work with you in the development of exactly the right equipment to accomplish your own exclusive requirements. For complete information write for our Bulletin No. 1080 or get in touch with your local Lindberg Field Representative (see your classified phone book). Semiconductor Equipment Division, Lindberg Engineering Company, 2489 West Hubbard Street, Chicago 12, Illinois.

Los Angeles plant: 11937 S. Regentview Avenue, Downey, California. In Canada: Birlefco-Lindberg Ltd., 15 Pelham Ave., Toronto 9, Ont. Also, Lindberg plants in Argentina, Australia, England, France, Italy, Japan, South Africa, Spain, Switzerland and West Germany.

"VISIT LINDBERG AT WESCON—Booth 4427"

Circle No. 14 on Reader Service Card

Lindberg equipment at Hewlett-Packard includes Diffusion Furnaces (foreground) and Tube Furnace (at back).

LINDBERG

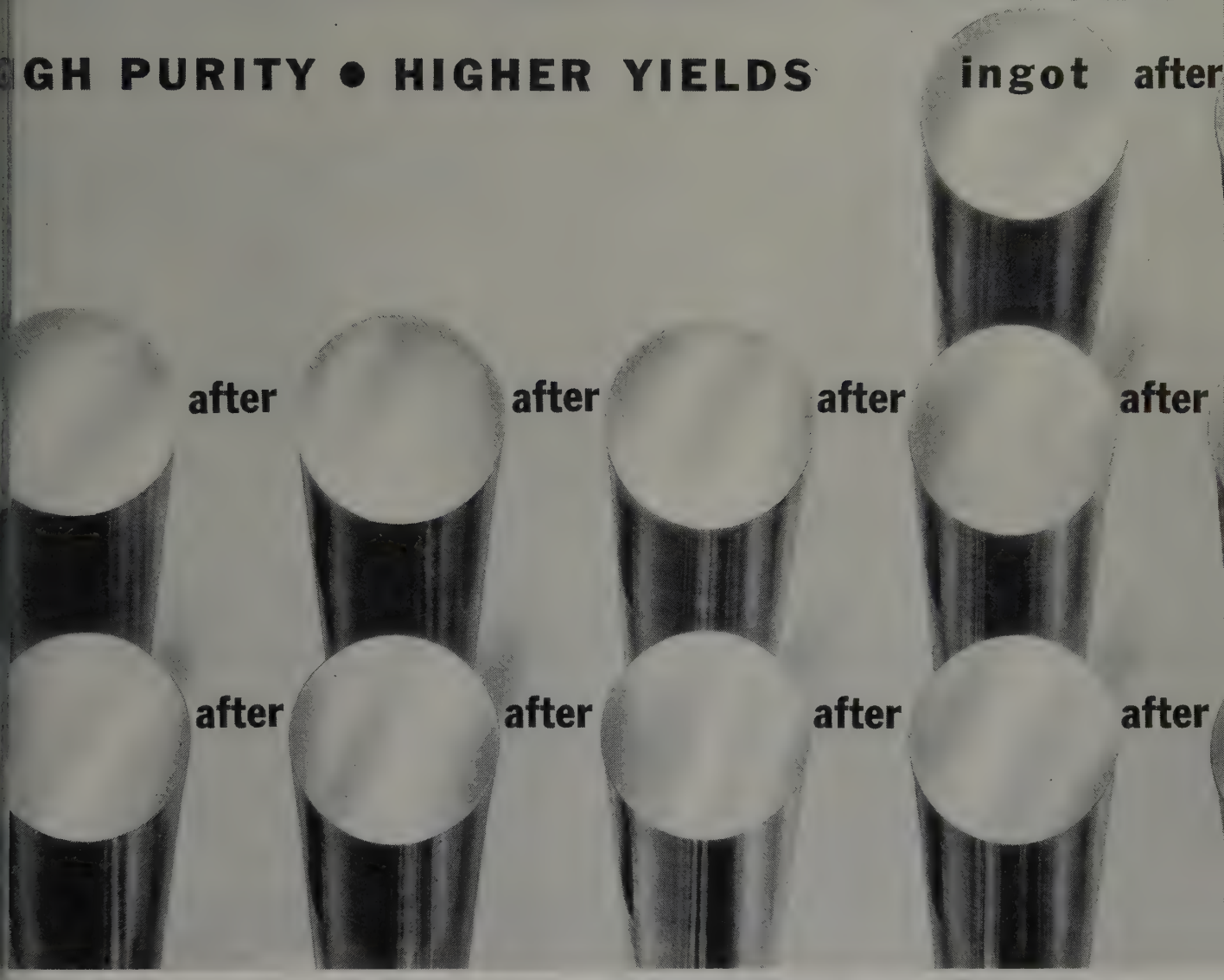
heat for industry

MONSANTO SILICON

n give you the profitable combination of

ONSISTENT REPRODUCIBILITY • UNIFORM

GH PURITY • HIGHER YIELDS



ngle crystal MONSANTO SILICON — float-zone-ined with parameters *precision-tailored* to customers' ecifications — assures these advantages:

- Extremely flat vertical and horizontal resistivity profiles
- Excellent crystal structure—*no slippage or lineage*
- Boron level in *n* type crystals less than 0.25 ppb—*for minimum compensation effect*
- Uniform radial and vertical dislocation density
- Low oxygen content—less than 1 x 10^{16} atoms per cc.
- Uniformly tight diameter control

ow your own? Find out how Monsanto micropure *poly-ystalline* silicon can help boost your ingot yield. Boron ntent guaranteed less than 0.25 parts per billion ypically less than 0.15 ppb).

Circle No. 15 on Reader Service Card

MONSANTO SILICON is being produced in this modern multimillion-dollar plant—backed by a 60-year tradition of "tailoring" materials to critical specifications.

Here, too—and at other R&D facilities—Monsanto Scientists and Technologists are developing promising new semiconductor materials and processing advances—including new poly and single crystal intermetallics. We cordially invite your inquiries.

Use the handy coupon

MONSANTO CHEMICAL COMPANY
Inorganic Chemicals Division
Electronic Chemicals Dept. 4213
St. Louis 66, Missouri

Monsanto

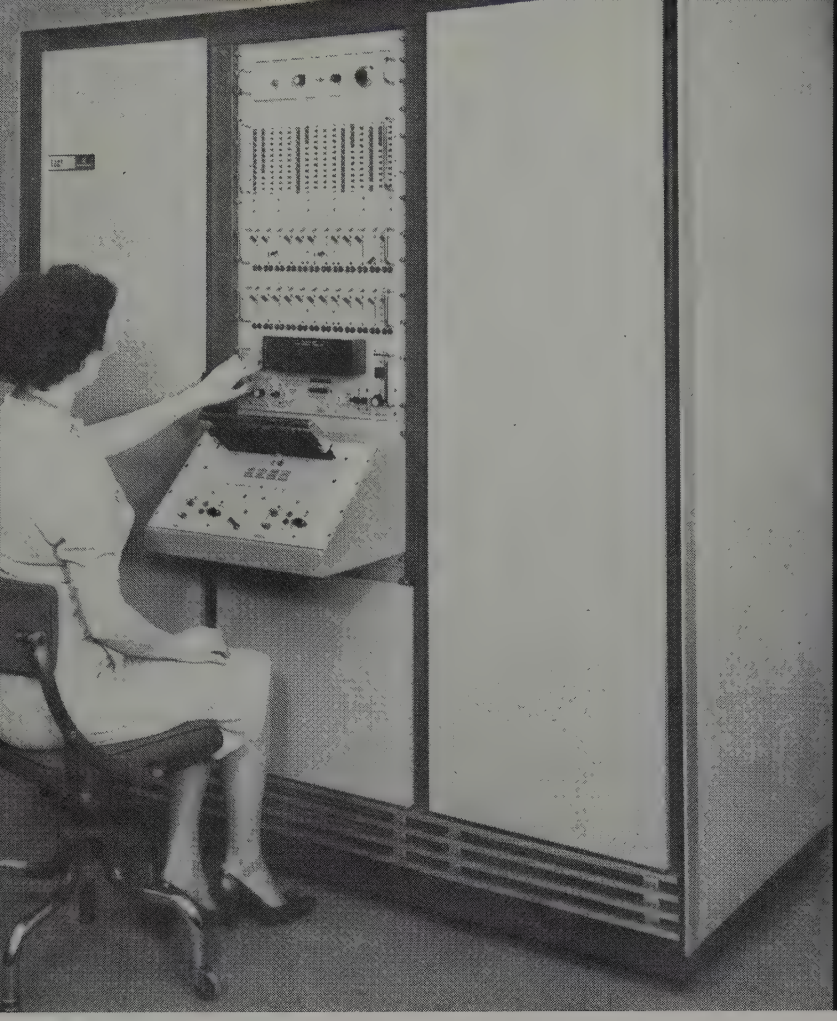
Please send me: ☐ Monsanto mono- and polycrystalline silicon specifications. ☐ Information about new intermetallics.

NAME .....

COMPANY .....

STREET .....

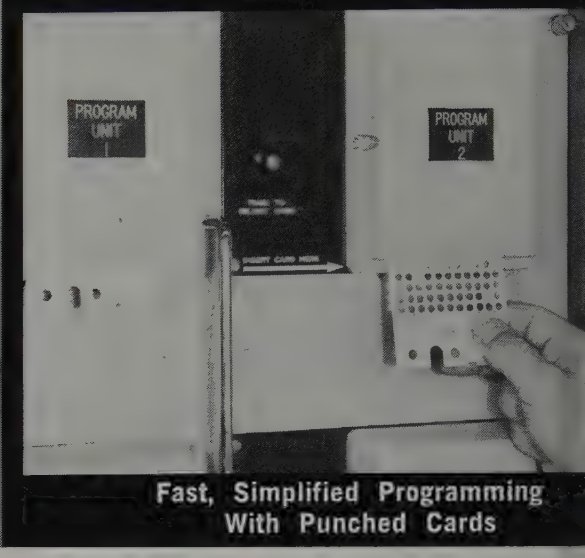
CITY ..... ZONE ..... STATE .....



new from TI

tact

TRANSISTOR AND COMPONENT TEST



Fast, Simplified Programming With Punched Cards

MAXIMUM VERSATILITY *PLUS* ECONOMY

tact BUILDING-BLOCK DESIGN GIVES YOU BOTH!

TACT is a universally applicable transistor and component tester that will meet both present and future requirements without undue investment. It is a sequentially controlled system which advances through as many as 24 test parameters, applying pre-programmed test limits and visually reading out and/or recording measured results. Time-proved test circuitry is combined with punched-card programming to produce a highly accurate system of high sequential testing speeds.

TACT systems won't become obsolete—can be expanded to accommodate future tests or extended to testing printed circuit boards, modular circuits, etc.

High Testing Accuracy results from reduction of readout and signal cable leakage and interference. Test circuitry cabling has been reduced to approximately one-tenth of other designs offering similar testing capabilities.

Repeatability of Testing is maximized by punched-card programming and remote control of common test circuitry. Program cards can be retained and used indefinitely, assuring high repeatability and a permanent record of test conditions.

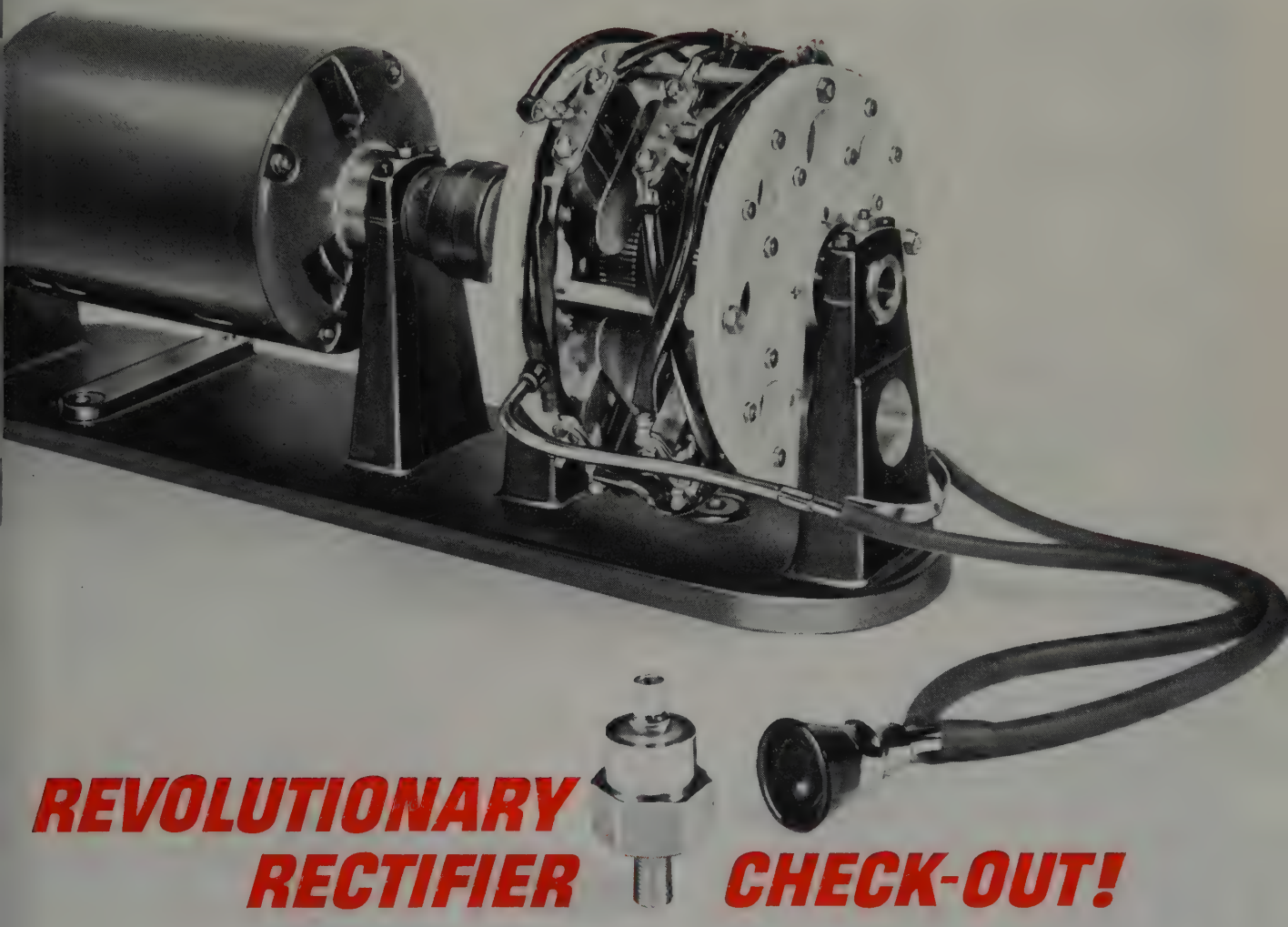
Nontechnical Personnel can operate TACT systems with minimum training. Reprogramming can be accomplished in minutes without circuit board or plug-in unit changes.

APPARATUS DIVISION
PLANTS IN HOUSTON
AND DALLAS, TEXAS

TEXAS INSTRUMENTS
INCORPORATED
3609 BUFFALO SPEEDWAY
P. O. BOX 6027 HOUSTON 6, TEXAS

Circle No. 16 on Reader Service Card

VEN/GENERAL MILLS
...Blazing new trails in component reliability!



REVOLUTIONARY RECTIFIER CHECK-OUT!

New synchronous switch gives more dependability . . .
lower initial cost, lower operating cost!

HERE is just what you need to test **large numbers** of semiconductor rectifiers under rated conditions of forward current and peak-inverse voltage—without dissipating the large power required by normal full-wave rectifier circuits. The forward current and peak-inverse voltage are applied for a larger portion of the cycle (170°) than test circuits using thyratrons, ignitrons, or relays.

The switch also includes these operating features: voltage drop less than 1 volt at maximum current rating (which is 100 amperes average through each bank of rectifiers in full wave circuit) . . . generation of destructive transients is non-existent . . . rectifiers may be tested in series on each side of circuit . . . 2 thermal cutouts, which operate at 200° F, can be used in breaker control or alarm circuits . . . unit furnished with enclosure and blower.

Write today for new technical literature!

THE **DAVEN** COMPANY, Livingston, New Jersey

A SUBSIDIARY OF GENERAL MILLS

General Mills

SWITCHES

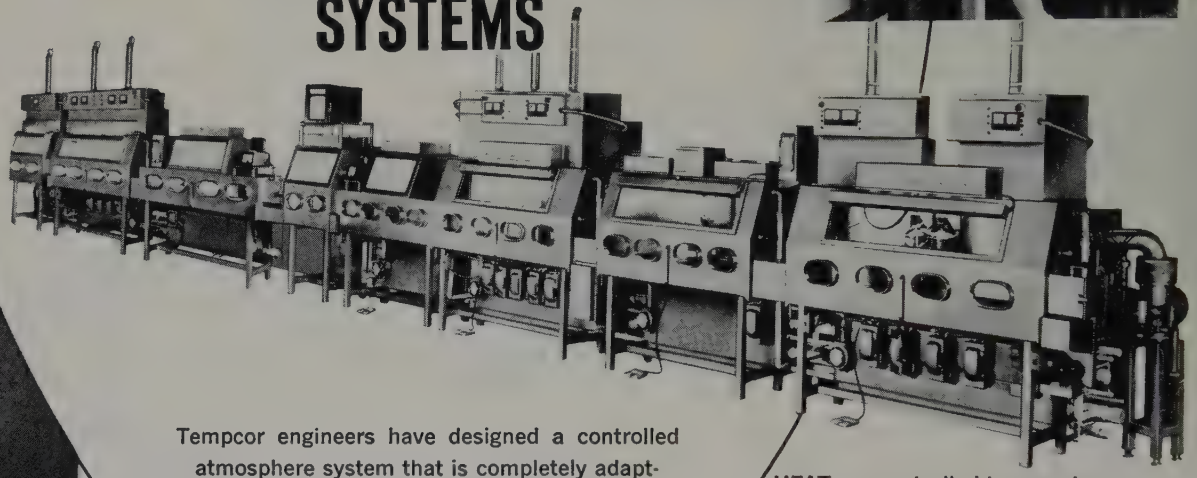
TODAY, MORE THAN EVER, THE DAVEN Ⓓ STANDS FOR DEPENDABILITY

The largest number of Dry Boxes used in the Semiconductor Industry have been manufactured by Temperature Engineering Corporation *

ACHIEVE ULTRA-HIGH RELIABILITY IN SEMI-CONDUCTORS

RCA, Hughes, Delco, Raytheon, Texas Instrument, Western Electric, Motorola, Sylvania and other leaders in the Semiconductor industry, whose manufacturing requirements are critical, rely on Tempcor Dri-Boxes and Dri-Box Systems.

TEMPCOR CUSTOM MODULAR DRI-BOX VACUUM BAKEOUT SYSTEMS



Tempcor engineers have designed a controlled atmosphere system that is completely adaptable to your specific requirements and processes. The flexibility of this system allows modifications and adaptions to meet changing processing and production requirements

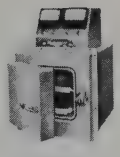
HEAT . . . controlled temperatures to 400°C.

VACUUM . . . to 1 x 10^{-6} MM hg or better.

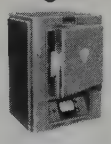
DEWPOINT . . . to —90°F in conjunction with Tempcor Molecular Sieve Dryers.

POSITIVE PRESSURE . . . to 3" of water column.

ENCLOSURES . . . special configurations available.



Vacuum Ovens*



Drying Ovens*

Automatic Recirculating Dryers*

Vacuum Gauges*

*Patents Pending

Temperature
ENGINEERING CORPORATION
Manufacturers of Constant Temperature, Vacuum and Controlled Atmosphere Equipment
100 Tempcor Boulevard, Riverton, N. J.

* Semi Conductor Magazine Industry Report June 1961

TEMPERATURE ENGINEERING CORPORATION
100 Tempcor Boulevard, Riverton, N. J.

I would like further information on TEMPCOR CONTROLLED ATMOSPHERE SYSTEMS without obligation.

☐ Send representative
☐ Send complete technical information

Name_____

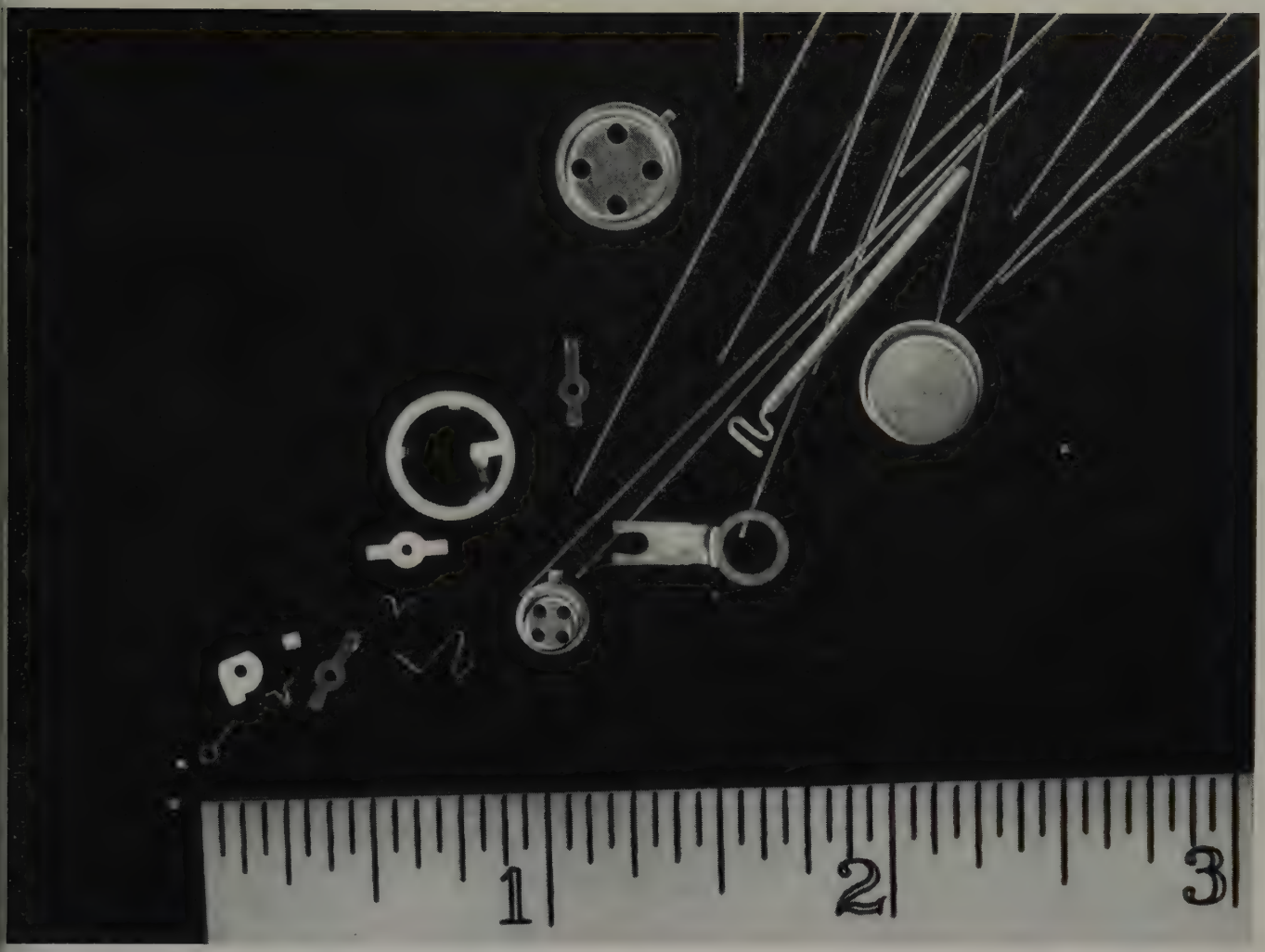
Title_____

Firm_____

Address_____

City_____ State_____

Circle No. 18 on Reader Service Card



NOW: All kinds of metal stampings and wire forms for semiconductors . . . by the millions!

From just a few feet away, some of these parts are all but invisible to the naked eye. Close up, each reveals the marvel of precision that marks all Sylvania parts custom-made for semiconductor device manufacturers.

You'll find our millions-of-parts-per-day facilities pay you big dividends whether you need caps or cups, clips or clamps, cuts or leads, heat sinks or headers. Our specialties? Stringent production schedules and incredibly tight tolerances.

Specifically, Sylvania maintains a tough-minded quality control department that even covers equipment tooling and inspection of incoming material. We even manufacture our own wire and ribbon to be sure of their quality. This thoroughness minimizes rejection rates and helps customers meet their own production schedules.

Our experience with a wide variety of materials means we can satisfy a greater number of special requirements. We have even developed our own equipment to handle unusual needs.

Total result to you: unsurpassed quality in semiconductor parts—even if you order millions of parts per day.

For further details—or a quote on a specific project—write Sylvania Electric Products Inc., Parts Division, Warren, Pa.

SYLVANIA

SUBSIDIARY OF

GENERAL TELEPHONE & ELECTRONICS

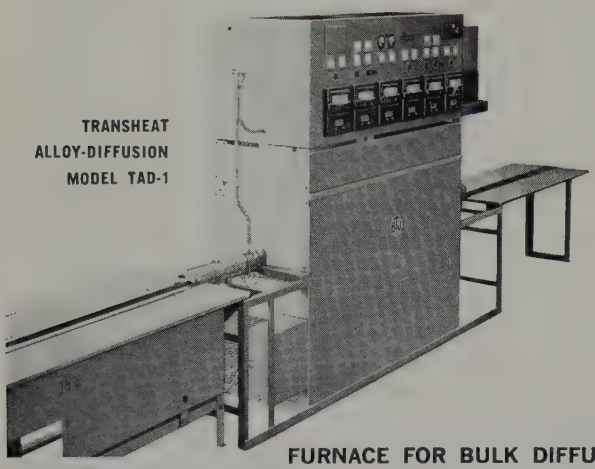
GENERAL SYSTEM

Circle No. 19 on Reader Service Card

LATEST FURNACE DEVELOPMENTS FROM BTU TO FULFILL SPECIAL NEEDS OF THE SEMICONDUCTOR INDUSTRY

The continued success of BTU Engineering Corporation has been due to its ability to translate special process requirements into operative equipment having precise control, dependability, repeatability . . . and *guaranteed performance*. Today's fast moving production development problems require equipment that can deliver performance to specifications without undue difficulties after delivery.

All BTU furnaces can be furnished with the exclusive Stepless Power Prop* which is a solid state stepless input control utilizing controlled rectifiers.



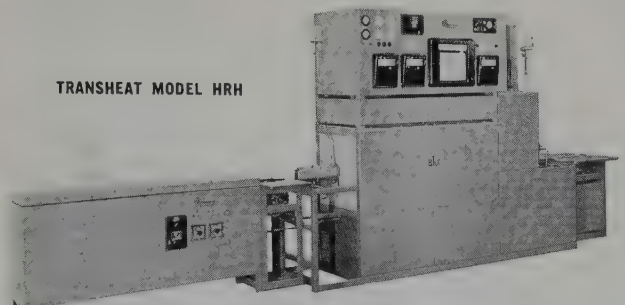
TRANSHEAT
ALLOY-DIFFUSION
MODEL TAD-1

FURNACE FOR BULK DIFFUSION

Bulk diffusion is a new process which combines alloying and diffusion into one operation. One of the unique features of the Transheat TAD-1 is its drive which feeds graphite boats through the muffle at a continuous constant speed without the use of a belt.

FEATURES

- High rate of heat rise with both an alloying flat and a diffusion flat held for any desired period of time.
- Precise control of temperature and atmosphere. Temperature tolerance on product: $\pm 1°C$.
- Maximum operating temperature: 1150°C.
- Cooling profiles precisely controlled at rates down to 1°C per minute or less.



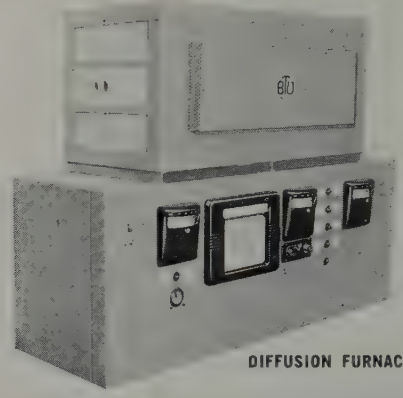
TRANSHEAT MODEL HRH

HIGH-RATE-HEATING ZONE* FURNACE FOR ALLOYING

Applications such as alloying Germanium with Indium for High Frequency Transistors require the highest possible rate of heat rise without overshooting, coupled with precisely controlled alloying flat and cooling profile.

FEATURES

- Specialized heat barrier prevents any significant heat exchange between HRH zone and alloying flat zone.
- Special transfer mechanism.
- Rapid heating rates up to 1500°C per minute (depending on load).
- Alloying flats up to 1100°C can be held to $\pm 1°C$ for any desired period of time.
- Cooling rates may be controlled down to 2°C per minute or less.
- Purity of atmosphere can be maintained to less than 1 part per million with low consumption of gas.



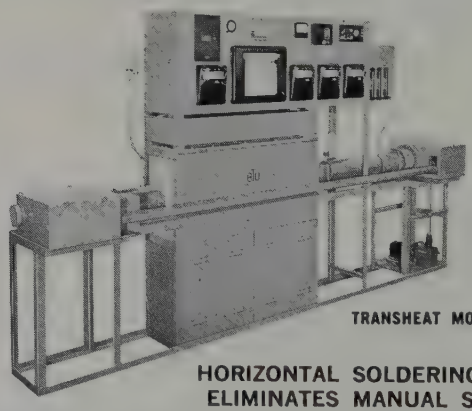
DIFFUSION FURNACE MODEL D2TR

TWO TUBE DIFFUSION FURNACE HAS DOUBLE CAPACITY WITH PRECISION CONTROL

This single two section diffusion furnace with 2 tubes side by side is equivalent to two conventional diffusion furnaces

FEATURES

- Has precisely matched performance in both tubes.
- No negative dip between source heater and main diffusion heater
- Source heater thermal flat: 4" $\pm 1\frac{1}{2}°C$ at 700° to 1100°C.
- Main diffusion heater thermal flat: 12" $\pm 1\frac{1}{2}°C$ at 1000° to 1300°C
- Maximum operating temperature: 1400°C.



TRANSHEAT MODEL TSH

HORIZONTAL SOLDERING FURNACE ELIMINATES MANUAL SOLDERING

Hydrogen atmosphere within this furnace eliminates the need for flux, and produces clean oxide-free bonds. Wetting action is superior to that produced with flux. It has a continuous horizontal closed loop chain drive with boats attached. Parts or preloaded fixtures are placed directly on the boats.

FEATURES

- Single station loading and unloading requiring fewer operators
- Operating temperatures to 600°C. Temperature profile on product controlled to $\pm 1°C$.
- Exclusive BTU H_2-N_2 gas control system with failsafe provision
- Elimination of flux and manual soldering — more uniform results
- Higher rates of production with lower costs.
- Flexible production setups adaptable to automation.
- Desired clearances can be provided below as well as above the fixture to accommodate leads, etc.

If you have furnace problems, consult

BTU ENGINEERING CORPORATION

SEMICONDUCTOR PRODUCTS DEPT.

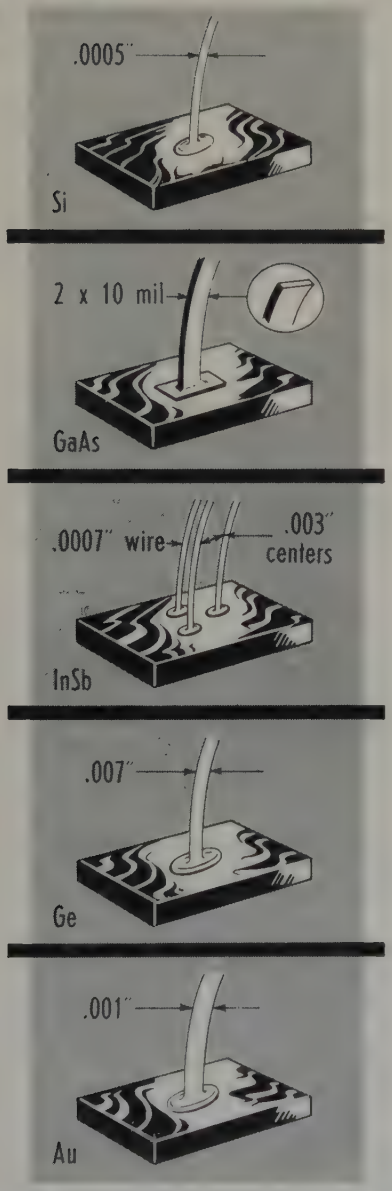
179P BEAR HILL ROAD, WALTHAM 54, MASSACHUSETTS, U.S.A., Tel. TW 4-6050

When in Boston, you are invited to visit our New Plant on Route 128 . . . "Electronics Highway"

*PATENTS

Circle No. 20 on Reader Service Card

CONTACT! (OHMIC)



How do YOU get in and out of the Solid State?

ELECTROGLAS NAILHEAD BONDER

Can bond gold wire to Si, to GaAs, to InSb
Can bond .0007" wire on .003" Centers
Can bond Ag to Si
Can feed and bond ribbons of various sizes
Can make bonds with superior mechanical strength

ELECTROGLAS INCORPORATED

Will deliver a standard machine in one week
Will supply a factory trained semiconductor experienced engineer in your plant within 72 hours upon request for demonstration
Will supply heated mounting surfaces machined to your specifications
Will supply special capillaries to your requirements

Contact Our
Field Sales-Engineering Offices:

Electroglas Inc.

IN THE WEST:	EASTERN SEABOARD:	IN NEW YORK
Chafin & Associates	Chafin & Associates	J. Lazor & Associates
1541 W. Olympic Blvd.	12 Fairview Ave.	280 E. Highland Ave.
Los Angeles, Calif.	Waltham, Mass.	Rochester, New York

841 WARRINGTON AVENUE • REDWOOD CITY • CALIFORNIA • TELEPHONE: EMerson 8-3346

Circle No. 21 on Reader Service Card

Market News . . .

Sales

The Electronics Division, Business and Defense Services Administration, U. S. Department of Commerce, has reported that annual totals show shipments of semiconductor devices has reached $542 million in 1960, up 37 percent from $395 million in 1959. Increases were shown also by most other categories of components, although receiving-tube output declined 7 percent from $374 to $348 million and output of power and special purpose tubes remained substantially unchanged at $252 million.

The appended tables give details by component category for the principal items for which data were collected.

Estimated Shipments of Semiconductors, during 1961[1]

Category	Quantity (in thousands of units)			Value (in thousands of dollars)		
	Total	Military	Non-military	Total	Military	Non-Mil.
SEMICONDUCTOR DEVICES	329,392	93,687	235,705	541,948	258,161	283,787
Diodes, rectifiers and related devices	197,570	70,180	127,390	228,021	114,081	113,940
Germanium diodes and rectifiers	97,472	31,756	65,716	49,071	22,363	26,708
0-30 ma	53,274	16,069	37,205	24,846	11,387	13,459
31-100 ma	36,319	12,893	23,426	18,428	9,052	9,376
Over 100 ma	7,879	2,794	5,085	5,797	1,924	3,873
Silicon diodes and rectifiers	81,195	33,651	47,544	129,240	68,523	60,717
0-30 ma	14,695	8,899	5,796	23,456	16,397	7,059
31-100 ma	16,957	9,509	7,448	29,910	19,031	10,879
101-550 ma	25,509	8,388	17,121	32,795	15,394	17,401
551 ma—3 amps	16,612	5,629	10,983	21,233	9,090	12,143
Over 3 amps—35 amps	6,905	1,016	5,889	13,755	4,744	9,011
Over 35 amps	517	210	307	8,091	3,867	4,224
Zener diodes	6,400	2,768	3,632	27,227	11,789	15,438
Microwave diodes	1,122	1,122	[2]	5,125	5,125	[2]
Infra-red and other semiconductor photo cells, except solar cells	321	95	226	2,693	1,776	917
Other[3]	11,060	788	10,272	14,665	4,505	10,160
Transistors	131,822	23,507	108,315	313,927	144,080	169,847
Germanium	121,274	16,263	105,011	207,247	65,360	141,887
0-125 mw	44,761	8,354	36,407	73,620	29,417	44,203
126-999 mw	60,484	6,186	54,298	95,194	24,643	70,551
1 watt and over	16,029	1,723	14,306	38,433	11,300	27,133
Silicon	10,548	7,244	3,304	106,680	78,720	27,960

[1] Estimated total industry shipments including intra-plant and inter-plant transfers.

[2] Nonmilitary shipments of microwave diodes were combined with military shipments to avoid disclosure of proprietary information.

[3] Includes diodes and rectifiers made from materials other than silicon and germanium, tunnel diodes, controlled rectifiers, solar cells, and other special semiconductor devices which must be combined to avoid disclosure of proprietary information.

Source: The quarterly Joint Survey of Production Capabilities for Electronic Parts conducted by the Electronics Production Resources Agency of the Department of Defense, and the Electronics Division, BDSA.

According to monthly figures released recently by the Marketing Data Department of the Electronic Industries Association, factory sales of transistors fell off during April, but year-to-date sales totals stayed well ahead of those for the same period last year.

	Factory Sales (Units)	*Factory Sales (Dollars)*
April	15,072,064	$27,388,278
March	15,129,273	29,815,291
February	13,270,428	25,699,625
January	12,183,931	22,955,167
Jan.-Apr. '61	55,655,696	105,858,361
Jan.-Apr. '60	41,047,034	101,444,855

General News

CBS states that it has dropped its receiver tube operation. The firm will close its plant in Danvers, which employs about 1000 along with plants at Newburyport, Mass., and North Windham, Me. A major part of their entertainment type receiving tube inventory will be purchased by Raytheon Co.

The production of the 25 millionth Precision-Etch transistor sold by Philco Corporation was celebrated at the Spring City Pa. plant of the firm's Lansdale Division recently. In a ceremony marking the milestone in transistor marketing, William J. Peltz, vice-president and General Manager of the Lansdale Division, paid special tribute to the U.S. Army Signal Corps for having joined the company in getting the first production of Precision-Etch transistors underway in 1955. Some two hundred people, including officers of the U.S. Army Signal Corps, Philco employees, and members of the press were in attendance at the celebration.

Alloys Unlimited, Inc. entered into a technical and selling agreement with a 300-year old Japanese industrial, financial and commercial complex, Sumitomo Shoji Kaishi, Ltd. Under the agreement, they will advise Sumitomo on the production of spheres, pellets, and base tabs. In return, they will be paid $50,000 down payment and royalties on all sales of these items for the next seven years. The Japanese firm will limit its operations to Asia and will not compete with Alloys Unlimited or its customers in Europe or the Western Hemisphere.

Suppliers

Sylvania Electric Products, Inc., has added type 2N1699, a drift field transistor, to its Pancake transistor line. This is a miniature version of their 2N1225 and is priced at $15 each in quantities from 1-99, and at $10 in quantities from 100 to 999.

Slater Electric, Inc., Glen Cove, N.Y., has introduced two diffused junction silicon rectifiers. Type SLA547 is available in production quantities at $1.11 each; type SLA5 series are likewise priced at 53¢ each.

The Crystal Products department, Linde, Co., East Chicago, Ind. has developed new semiconductor alumina powders for the critical polishing of silicon and germanium wafer surfaces. Three basic particle size ranges of the alumina are in production with each costing about $15 a pound. Four ounce samples are available on request.

Mallory Semiconductor Co., has introduced a silicon rectifier voltage doubler device designed to perform the functions of two individual rectifiers. The devices are priced at 85¢ each in quantities of 1000.

Trygon Electronics, Inc., Roosevelt, L.I., N.Y. has developed a series of modular transistorized power supplies designed for "plug-in" type of operation. Price is $184 each.

Fairchild Semiconductor, Inc., is in production of a silicon planar logic transistor with a complete switching cycle of 6NSEC maximum. Designated FT1310 these units are priced at about $20 each in quantities of 1-99 and about $14 to $15 in quantities of 100-999. Types 2N656 and 2N657, low-watt, medium power, silicon planar transistors are also available at $10 and $6.70 each respectively in similar quantities.

Microwave Associates, Inc., Burlington, Mass., has developed a glass-case mixer diode for applications in the 1-4000 mc region. Model 1N831A with an over-all noise figure equivalent to that of the 1N21WE, is designed for mounting in coaxial circuits for broadband low-noise mixer applications. Prices are not yet announced.

Equipment designed to cut costs, save time and increase production for the semiconductor and microcircuit industries was demonstrated recently by Kulicke and Soffa Manufacturing Company, Inc., in their new headquarters and assembly plant, Philadelphia, Pa. Equipment exhibited included: Model 401C for making microcircuits, Model 310 Production Probe, three pieces of equipment for scribing wafers, four pellet mounting machines, five wire bonders.

(Continued on page 56)

For uniform slicing . . .

uniform dicing . . .

uniform Norton diamond wheels save costly semiconductor materials

Are *you* adding to the already high price you pay for germanium, silicon, quartz, etc. — by permitting unnecessary waste in your wafering or slicing operations?

You can avoid this steady loss by using Norton diamond cut-off wheels — engineered to help you get *more* slices, pellets or dice out of every ingot of costly electronics material. Available in thinnesses as extreme as .004″, these wheels cut fast, free and straight — with non-chipping action that reduces waste to minimum.

Norton wheels slice and dice more accurately and save more valuable material . . . because dimensional accuracy is built into the wheels themselves . . . with constant uniformity. This is particularly important in gang dicing . . . where even one slight variation in wheel thinness will affect the accuracy of the group.

Backed by long leadership in the introduction and development of diamond wheels, Norton brings you a complete line. For prompt service see your Norton Distributor. Or write to NORTON COMPANY, General Offices, Worcester 6, Massachusetts.

NORTON
ABRASIVES

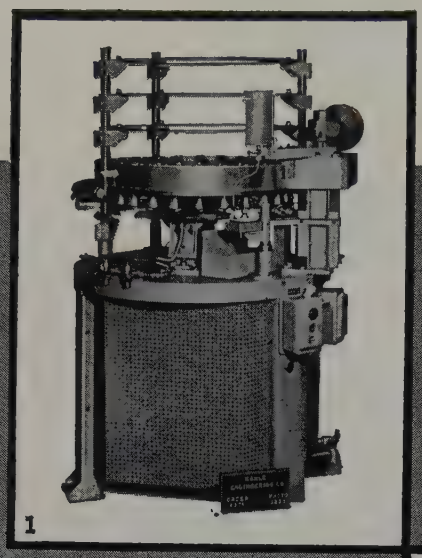
W-2021

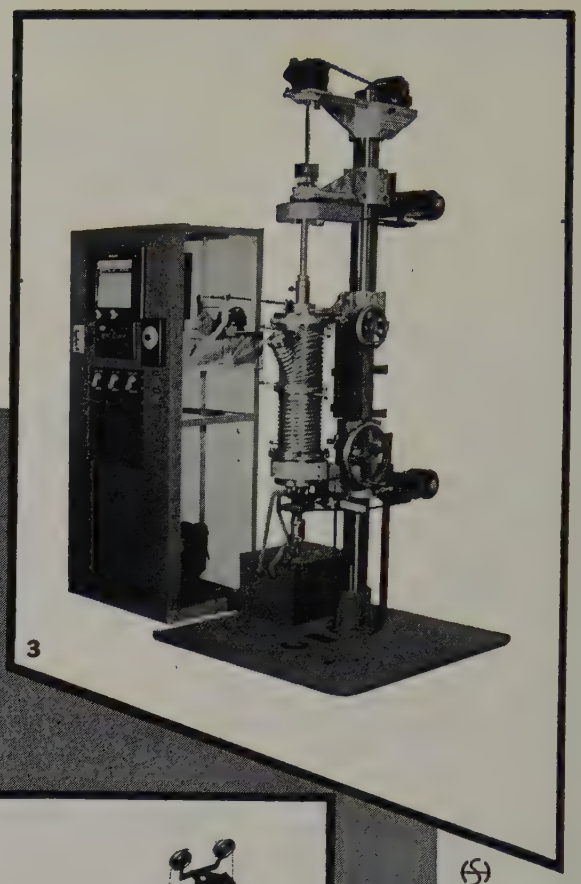
Making better products . . . to make your products better

NORTON PRODUCTS: Abrasives • Grinding Wheels • Machine Tools • Refractories • Non-Slip Floors — BEHR-MANNING DIVISION: Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes

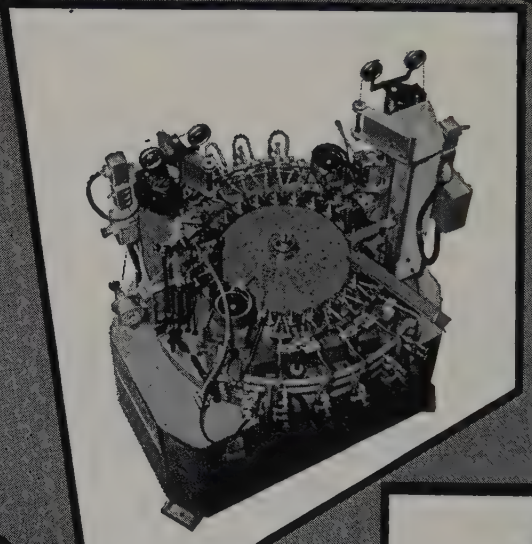
Circle No. 23 on Reader Service Card

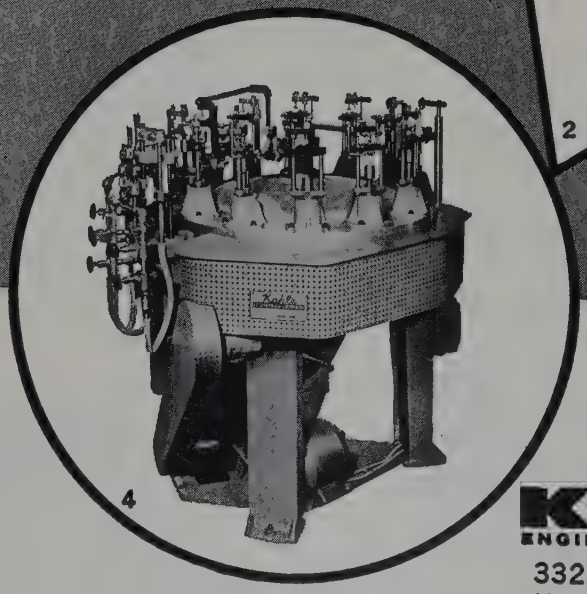
1 HIGH SPEED GLASS TUBING CUTTER
2 AUTOMATIC DIODE BEAD MACHINE
3 AUTOMATIC CRYSTAL GROWER
4 TRANSISTOR STEM (HEADER) MACHINE
5 AUTOMATIC CAT WHISKER WELDER

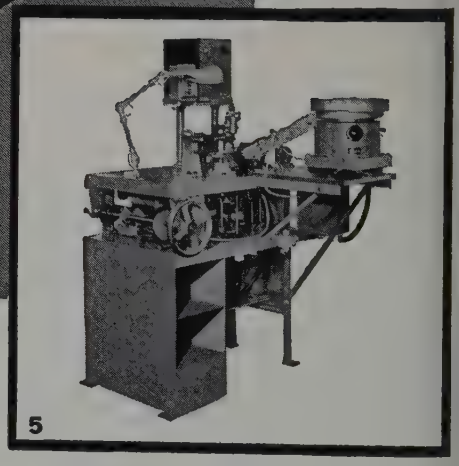

1


3

AUTOMATIC MACHINES
FOR SEMICONDUCTOR PRODUCTION
Higher output at lower cost
for every operation
from crystal growing to final test


2


4


5

KAHLE
ENGINEERING COMPANY
3322 Hudson Avenue
Union City, New Jersey

Designers and Manufacturers of Automatic Machines

Circle No. 24 on Reader Service Card

Editorial . . .

Radiation Damage in Semiconductors

The characteristics of semiconductors which depend upon the minority carriers are highly sensitive to the presence of impurities, defects and recombination centers. While this property demands the use of highly specialized techniques for the purification and crystal formation of the materials, it can also be utilized for the measurement of the formation of such defects. For example, it is well known that bombardment by high energy particles (electrons, neutrons, alpha particles, etc.) causes the formation of added levels in the forbidden gap. Thus, in the case of silicon bombarded with high energy electrons, levels at 0.03, 0.17 and 0.4 ev below the conduction band and 0.055 and 0.27 ev above the valence band have been observed (see K. Wertheim—*Phys. Rev.* 1957; D. Hill—*Phys. Rev.* 1959).

Transistors may be used as measuring devices. More recently it has been observed that tunnel diodes can also be utilized as such because their excess current is highly sensitive to the distribution and relative population density of levels in the forbidden gap.

The application of semiconductor devices for the measurement of radiation fluxes tends to displace such instruments as Geiger tubes which are based on the ionization of a gas discharge under high potential difference. Semiconductor devices require much lower operating voltages. For example, silicon tunnel diodes require approximately 0.3 V bias. The difficulties presented by their use is in the realization of an accurate calibration and in the cancellation of the effects of the radiation for re-utilization of the devices.

In a recent study (Logan, Augustyniak and Gilbert—*Jour. Appl. Phys.* July 1961) the behavior of silicon tunnel diodes under high energy (1 Mev) electron bombardment has been investigated. N-type silicon with phosphor, arsenic or antimonium doping was used. An aluminum wire with 1% boron was alloyed onto the silicon. The bombardment was effected in vacuum at 300° K and at 78° K, integrating the constant electron flux over time. It was found that the excess current increases linearly with the radiation flux with a constant of proportionality which is independent of temperature. With phosphor dopant the constant is 1.2×10^{16} amp^{-1}, and with arsenic or antimonium it is about 0.8×10^{16} amp^{-1}; i.e. p-doped diodes require about 50% more bombardment than As- or Sb-doped diodes for the same variation of excess current. The calibration shows about 30% mean deviation over measurements of several diodes. The damage of radiation may be removed by annealing the diodes at high temperature. Even at room temperature some reduction of the increased excess current is observed.

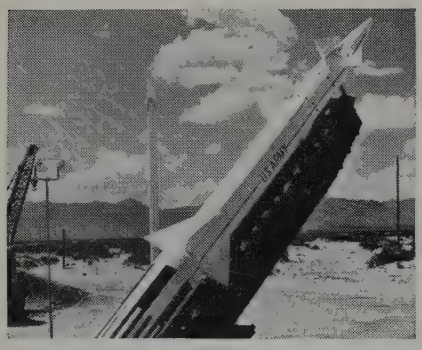
What was Bell Telephone Laboratories doing

ON FRIDAY, JUNE 30, 1961?

It was exploring the communications possibilities of the gaseous optical maser – a device which generates continuous coherent infrared radiation in a narrow beam.

It was preparing an experiment in world-wide communications using "active" satellites powered by the solar battery, a Bell Laboratories invention.

It was completing the development of a new "heavy route" Long Distance microwave system capable of handling over 11,000 two-way conversations at once.



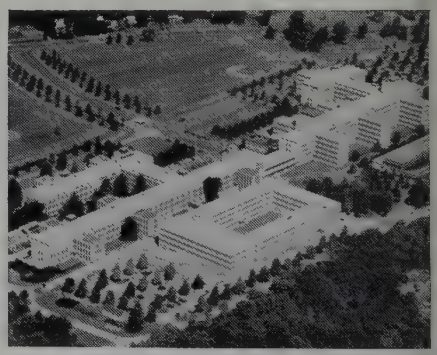
It was developing an anti-missile defense system designed to detect, track, intercept and destroy an enemy ICBM – in a matter of minutes.

It was demonstrating the potentialities of the superconducting compound of niobium and tin for generating, with little power, magnetic fields of great strength.

It was experimenting with an electronic central office at Morris, Ill., which is capable of providing a wide range of new telephone services.

It was perfecting the card dialer which permits, through insertion of a punched card into a slot, automatic dialing of frequently used numbers.

It was developing improved repeaters or "amplifiers" to increase greatly the capacity and economy of undersea telephone cable systems.



It was continuing its endless search for new knowledge under the leadership of scientists and engineers with world-wide reputations in their chosen fields.

Bell Laboratories scientists and engineers work with every art and science that can benefit communications. Their inquiries range from the ocean floor to outer space, from atomic physics to the design of new telephone sets, from the tiny transistor to massive transcontinental radio systems. The goal is constant—ever-improving Bell System communications services.

BELL TELEPHONE LABORATORIES

World center of communications research and development

Circle No. 25 on Reader Service Card

Transistor Pulse Amplifiers

V. G. K. REDDI*

The design of pulse amplifiers with transistors in the common emitter configuration using emitter degeneration (series current feedback) and collector-to-base feedback (parallel voltage feedback) is discussed. In a two stage amplifier a combination of the two feedback methods is found to be better than having both stages employ the same type of feedback. The main consideration has been given to the design of amplifiers for good pulse response rather than flat gain vs. frequency characteristics. A four-stage amplifier using Fairchild 2N706 transistors was built. The output pulse rise time was 10 nsec or less with no overshoot and an insertion voltage gain of 36 db was obtained (load and source impedance = 50 ohms).

THERE ARE TWO KINDS of video amplifiers. One is an amplifier designed to give flat gain vs. frequency response for desired bandwidth and the other is designed for pulse amplification with no overshoot for desired rise-time. Pulse response in the first case results in considerable overshoot unless the bandwidth is in the neighborhood of $1/2T_r$, where T_r is the rise-time of the input pulse. There are four commonly used circuit configurations in transistor video amplifiers: series peaking, shunt peaking, emitter degeneration and collector-to-base feedback.

We will be concerned in this article mainly with the latter two methods; namely, emitter degeneration and collector-to-base feedback. It is of interest to note that distributed amplifier techniques can be successfully used with transistors for large bandwidths, but it is felt that they do not offer any real advantage over feedback techniques when lumped elements are used to simulate input and output lines. The reason is that with present day high frequency transistors ($f_T \backsim 1$ kmc), bandwidths up to 250 mc with reasonable gain can be obtained with feedback techniques using conventional circuitry. The only advantage of distributed amplifiers over conventional ones is their capability of producing high voltage outputs.

The usual technique of obtaining a flat gain vs. frequency characteristic in a multistage video amplifier using either of the feedback methods under consideration is by staggering the peaking of different stages of the amplifier. Grinich (Ref. 2) has analyzed this problem on a formal basis and used a pair of emitter degenerated stages to obtain a gain function which has two poles. By cascading such pairs an all pole transfer function is obtained, and poles could be arranged in the complex frequency plane to lie equally spaced on a circle giving a Butterworth response. The same technique can be used with collector-to-base feedback stages since the gain functions in both cases are similar.

If one has access to a good sweep oscillator, it is a simple matter to adjust the feedback networks of a three or four stage amplifier to give a fairly flat gain vs. frequency characteristic by looking at the response on a scope. For this, the approximate values of the feedback elements and interstage loading to give desired gain and bandwidth should be known. In the case of amplifiers designed for good pulse response, more careful considerations are required.

The two feedback methods are discussed in some detail, as they form the basis for amplifier design. For this a single stage analysis is considered.

Single Stage Emitter Feedback Amplifier (Fig. 1)

If an emitter feedback stage is driven by an ideal current source, the bandwidth is less than ω_β and is independent of emitter feedback impedance to a first approximation. Hence gain-bandwidth trade is not possible. A voltage source is a more appropriate driving source in this case.

When $Z_e = R_e$, the voltage gain function of e_o/e_s has one pole on the negative real axis [Eq. A(3)].

The low frequency voltage gain A_{vo} [Eq. A(4)] and the 3 db bandwidth B_v [A(3), A(22) and A(23)] are:

$$A_{vo} = \frac{\beta R_L}{R_s + R + r_{b'} + (\beta + 1) R_e}, \qquad (1)$$

$$B_v = \omega'_\beta \left[\frac{R_s + r_{b'} + R + (\beta + 1) R_e}{R_s + r_{b'} + R_e} \right], \qquad (2)$$

where ω'_β is defined as:

$$\omega'_\beta = \frac{\omega_\beta}{1 + K\omega_T R_L C} \qquad [\text{see A(22)}]$$

(See appendix for explanation of notation.)

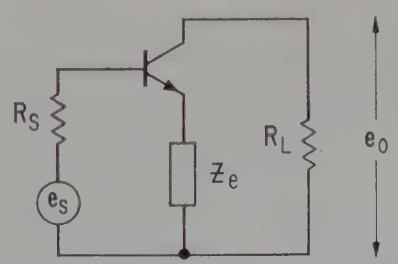


Fig. 1—Emitter feedback amplifier.

*Fairchild Semiconductor Corporation
Mountain View, California

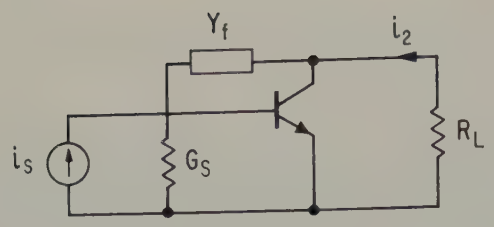


Fig. 2—Amplifier with collector-to-base feedback.

The voltage gain bandwidth product

$$= A_{vo} B_v = \frac{\beta \omega'_\beta R_L}{R_s + r_{b'} + R_e} \tag{3}$$

The rise time for pulse response

$$= \frac{2\pi \times 0.35}{B_v} \simeq \frac{2.2}{B_v}. \tag{4}$$

Voltage gain bandwidth product (VGBP) is maximum when $R_s = 0$. From this it is seen that for a low impedance driving source, an emitter feedback stage allows wide gain-bandwidth trading and gives good VGBP. By connecting a capacitance C_e across R_e in the emitter and with the condition that no overshoot appears in the pulse response, a rise-time-improvement factor η [see A (9) for definition] of better than 1.44 can be obtained. For this the condition is:

$$\omega_e = \frac{1}{R_e C_e} = \frac{4B_v}{1 + \dfrac{R_e}{R_s + r_{b'}}}. \tag{5}$$

The low frequency gain remains the same as the gain of the stage without peaking capacitance. An exact value of rise-time-improvement factor η as a function of $\dfrac{R_e}{R_s + r_{b'}}$ is shown in Fig. 12. When $\dfrac{R_e}{R_s + r_{b'}} = 1$, the zero gain function cancels one of the poles [Eq. A (8)] and $\eta = 2$. Values of

$$\frac{R_e}{R_s + r_{b'}} > 1$$

are of no interest. Even though we could get higher values of η for larger values of R_e (R_s and $r_{b'}$ remaining constant), the gain bandwidth product decreases for increasing values of R_e (Eq. 3). In the emitter feedback amplifier, the transistor output looks like a constant current source to the load (not considering effects of C_e and C_{bc}).

Single Stage Collector-To-Base Feedback Amplifier

In this case if the driving source is a constant voltage source, the bandwidth is less or equal to

$$\omega'_\beta \left(\frac{r_{b'} + R}{r_{b'}} \right)$$

and is independent of feedback impedance to a first approximation. Hence a low impedance source will not allow wide bandwidth variations with this feedback method. We will consider a current source at the input as shown in Fig. 2. When $y_f = G_f = 1/R_f$, the low frequency current gain (A_{io}) and the 3 db bandwidth (B'_i) are [A (13), A (14) and A (22)],

$$A_{io} = \frac{i_2}{i_s} = \frac{\beta G_L}{(G_f + G_L)\,[1 + (G_f + G_s)\,(R + r_{b'})] + G_f \beta} \tag{6}$$

$$B'_i = \omega'_\beta \left[\frac{1 + (G_f + G_s)\,(R + r_{b'}) + \dfrac{G_f \beta}{G_f + G_L}}{1 + (G_f + G_s)\, r_{b'}} \right] \tag{7}$$

Thus, current gain x Bandwidth $= A_{io} B'_i$

$$= \frac{\omega'_\beta \beta G_L}{(G_f + G_L)\,[1 + (G_f + G_s)\, r_{b'}]} \tag{8}$$

The current gain bandwidth product is maximum when $G_s = 0$; i.e., when the driving source is an ideal current source.

Let B_i be the bandwidth with $G_s = 0$.

$$B_i = \left[\frac{1 + G_f\,(R + r_{b'}) + \dfrac{G_f \beta}{G_f + G_L}}{1 + G_f\, r_{b'}} \right] \omega'_\beta \tag{9}$$

The rise time for a current pulse response is:

$$\frac{0.35 \times 2\pi}{B_i} \simeq \frac{2.2}{B_i} \tag{10}$$

Henceforth, we will consider only the case where $G_s = 0$. As in the emitter feedback case, one can improve the rise time without introducing any overshoot in the pulse response by connecting an inductance L_f in series with the feedback resistance R_f. The value of the inductance L_f can be computed from:

$$\omega_f = \frac{R_f}{L_f} = \frac{4B_i}{1 + \dfrac{r_{b'} + R_L}{R_f}} \tag{11}$$

[A (9)]

The values of η the rise-time improvement factor for $\dfrac{r_{b'} + R_L}{R_f}$ in the neighborhood of or less than 0.2 are not useful since this case corresponds to higher values of R_f or smaller bandwidths where the approximations used in deriving the above equations cannot be justified.

Two Stage Amplifier

Let us consider a two stage amplifier (Fig. 3) using a combination of both feedback methods discussed above. Considering the second stage with shunt voltage feedback, we saw that best current gain bandwidth can be obtained by driving it with an ideal current source. Such a situation can be provided by driving the last stage with the emitter degenerated amplifier stage since the output impedance of the stage is very high and its output is very nearly a current source in the frequency range of interest. R_s should be small in the first stage, for best transfer admittance $\left(\dfrac{i_l}{e_s}\right)$ x bandwidth. In situations where

driving source impedance is small these types of feedback arrangements utilize the potential of the transistors in the best possible manner. Each stage can be designed independently starting from the last stage since the interaction between stages is not considerable. It is complicated to prove algebraically that this type of two stage amplifier is better than employing both the stages with the same type of feedback, since the variables become too numerous when design equations are written for the three kinds of amplifiers under the same conditions of performance. However experimentally it has been observed with a two stage amplifier ($R_g = R_L = 50$ ohms) that the amplifier arrangement shown in Fig. 3 gave best overall voltage gain/rise time and next best was employing collector-to-base feedback for both stages. The least desirable arrangement was to use emitter feedback in both stages. For larger gains, the above described transistor pair arrangement can be cascaded. The design procedure can be well demonstrated by taking a specific example.

*Design of a Two-Stage Amplifier for a Specified Rise Time

Specification: $R_g = R_L = 50$ ohms
Rise time for pulse response with no overshoot
$= 7$ mμsec.

For design and experimentation purposes Fairchild 2N706 transistors are considered. Average values of the parameters are as follows:

($V_{CB} = 10$ volts,	$I_E = 10$ mA). See Fig. 8
$f_t = 300$ mc	$r_{b'} \sim 70$ ohms
$C_c = 1.5$ pf	$r_{e'} = 2.7$ ohms
$C_{bc} = 3$ pf	$r_{e''} = 2$ ohms
$\beta = 50$	

Two important properties of multistage pulse amplifiers are that if individual stages are designed for monotonic or non-overshoot pulse response, the overall rise time is the root mean square of the individual rise time of the stages; and further, that for given gain, the best overall rise time results when all stages are designed to have the same rise time (Ref. 1). Here it is assumed that there is no interaction between stages. In our case this is nearly satisfied. Each stage rise time has to be 5 mμsec to give an overall rise time of approximately 7 mμsec.

Let us consider the last stage with collector-to-base feedback. $R_L = 50$ ohms. From Eq. A (22) and A (23) we get

$$f_{t'} = \frac{300 \times 10^6}{1 + k\omega_T R_L C}$$

$$= 231 \text{ mc},$$

where $k = 0.7$
$C = C_c + C_{bc} = 4.5$ pf

To start with, let us assume a rise-time-improvement factor of 1.67 which corresponds to

$$\frac{r_{b'} + R_L}{R_f} = 0.55 \qquad \text{(Fig. 12)}$$

and design the feedback stage and check later whether the starting assumption is approximately correct. If it is not, we may have to repeat the process. For $\eta = 1.67$, the rise time of the stage with no reactive peaking (i.e., $L_f = 0$) should be $5 \times 1.67 = 8.35$ mμsec. This corresponds to a bandwidth of 41.9 mc. From Eq. (9) the value of R_f can be calculated for this bandwidth and in this case $R_f \simeq 220$ ohms. [In Eq. (9) R in this case is equal to $(r_{e'} + r_{e''})\ \beta$. See appendix and Fig. 8]

$$\frac{r_{b'} + R_L}{R_f} = 0.546$$

and for this value η is very close to 1.67 and the assumption made at the start is correct. In general, the agreement will not lie so close and usually requires redesign. The required inductance L_f for rise-time-improvement can be calculated from Eq. (11) and is equal to $L_f = 0.323$ μh. Low frequency current gain $A_{io} = \frac{i_2}{i_1}$ (Fig. 3) can be calculated from Eq. (6) by letting $G_s = 0$.

$$\frac{i_2}{i_1} = 3.5, \quad \frac{e_o}{i_1} = -3.5 \times 50 = -175 \text{ ohms}.$$

The low frequency input impedance of this stage R_{IN} is given by

$$R_{IN} = \frac{A_{io}\,(R + r_{b'})}{\beta/(1 + R_L/R_f)} = 26.0 \text{ ohms}$$

Consider now the first stage with emitter feedback which is loaded by the input of the second stage. At low frequencies it is equal to R_{IN}. At higher frequencies the impedance varies and the variation is within a factor of two of R_{IN}. We will take R_{IN} as the load of this stage to calculate ω'_β or ω'_T.

Using Eq. A (22) and A (23) we get

$$f'_t = 246 \text{ mc} \quad (k = 1,\ R_L = R_{IN} = 26 \text{ ohms})$$

The desired rise time of this stage is 5 mμsec.

*Since this work, an amplifier has been built using the more recent 2N917 transistors. This resulted in a 2 nanosecond rise time and a 12 db gain for two stages. See ref. 7.

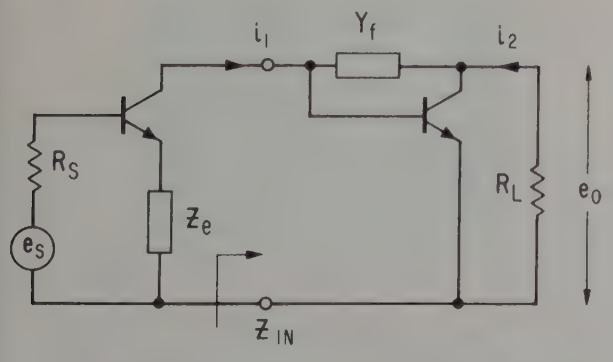


Fig 3—Generalized two stage amplifier

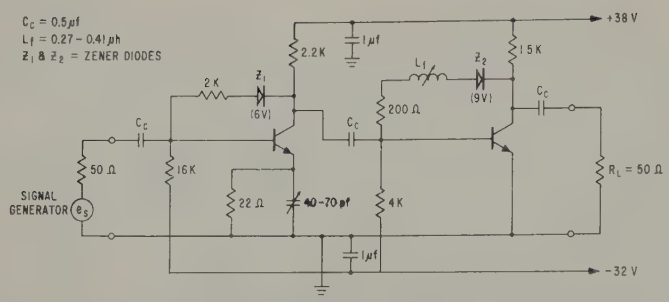


Fig. 4—Two stage amplifier designed to specifications.

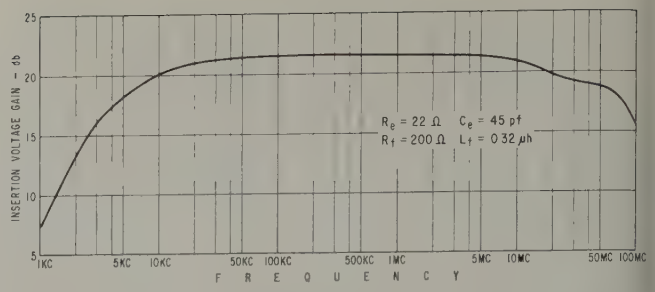


Fig. 5—Frequency response of the two stage amplifier shown in Fig. 4.

Proceeding as in the previous case, let us assume a rise-time-improvement factor $\eta = 1.47$ which corresponds to

$$\frac{R_e}{R_s + r_{b'}} = 0.16.$$

Rise time without capacitive peaking $= 5 \times 1.47 =$ 7.35 mμsec. This corresponds to a bandwidth $B_v =$ 47.7 mc.

For this bandwidth the required value of R_e we get from Eq. 2 (R here is equal to $r_{e'\beta}$) and is equal to 22.5 ohms.

$$\frac{R_e}{R_s + r_{b'}} = 0.188.$$

This corresponds to $\eta = 1.48$ (Fig. 12) which is very close to the value assumed to start with (1.47). As mentioned earlier, it may be necessary to repeat the procedure if the agreement is not close. The peaking capacitance C_e is now calculated using Eq. (5) and is equal to 44 pf.

Low frequency transconductance $\frac{i_1}{e_s}$ (see Fig. 3) can be estimated from Eq. (1) and is equal to —1/28 mhos.

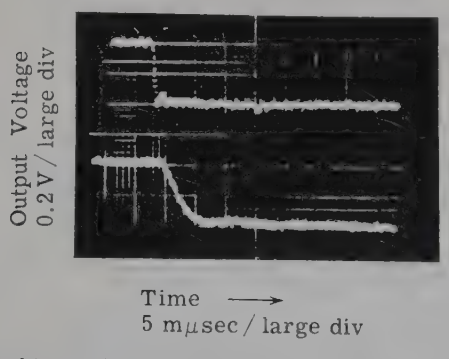
R_f = 220 ohms	R_e = 22.5 ohms
L_f = 0.32 μh	C_e = 44 pf

Insertion voltage gain = 22 db
Rise time of each stage = 5 mμsec
Overall rise time = 7 mμsec.

Ordinarily the value of R_e to be connected will be less than the calculated value by an amount equal to $r_{e''}$ the emitter body and contact resistance.

Experimental Results

An amplifier based on the above design was built and the complete circuit is shown in Fig. 4. The frequency response is plotted in Fig. 5. Measured midband insertion voltage gain was 21.5 db. Pulse response of the amplifier is shown in Fig. 6. Both input and output pulses are shown on the same oscillogram to display the delay characteristic. Pulse response was measured with a Lumatron Sampling Scope using the built-in pulse generator. The input pulse rise time was about 0.5 nsec, and the output pulse rise time was less than 6 nsec. ($R_e = 22\Omega$, $C_e = 60$ pf, $R_F = 200\Omega$, $L_f = 0.35$ μh.) The rise time can be improved by increasing slightly the reactive peaking elements (C_e and L_f) but at the expense of overshoot in the pulse response. Further increases of L_f and C_e result in oscillatory type of overshoot. A linear negative pulse output up to one volt could be obtained with very little degradation in the pulse shape. For large positive pulse outputs quiescent bias values should be different than those shown in Fig. 4. The pulse response of a four stage amplifier (two identical two stage amplifiers in cascade) is shown in Fig. 7. The output pulse has no overshoot and the rise time was close to 9 nsec. Insertion voltage gain was 36 db. The biasing scheme using Zener diodes was found to be very satisfactory from thermal stability and low frequency response considerations. [Ref. (6).] Low frequency 3 db cut-off of the two stage amplifier was



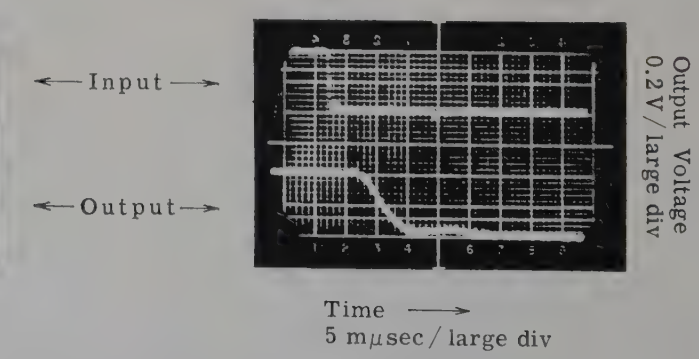


Fig. 6 (Left)—Pulse response of a two stage amplifier. Insertion Voltage Gain = 21.5 db; Rise Time ≅ 6.0 mμsec.

Fig. 7 (Right)—Pulse response of a four stage amplifier. Insertion Voltage Gain = 36 db; Rise Time ≅ 9 mμsec.

.5 kc. In the breakdown region, the Zener diodes sed in the biasing scheme appeared to be nearly 20 Ω n shunt with 1.5 μh inductance. To take this into ccount the value of R_f connected in the collector-to- ase feedback stage was reduced by 20 Ω from the alculated value. Care should be taken to ensure that ne Zener diodes remain in conduction when large egative voltages appear at the collector; if this pre- aution is not taken, the collector-to-base feedback etwork will be disconnected under these conditions.

onclusion

Fast pulse amplifier design using transistors has been considered. Two feedback methods (emitter feedback and collector-to-base feedback) have been discussed in some detail. A combination of the above two feedback methods in a two stage amplifier was found to give best overall voltage gain/rise time. Design equations were derived using an approximate equivalent circuit of the transistor, and have been modified to take into account the internal feedback of the transistor. A design example has been worked out using the equations derived in the text. The performance of the amplifier built, based on the above design, agreed quite well with the calculated values.

Appendix

A complete analysis of the emitter feedback case was orked out by Bruun (Ref. 4) and of the collector-to- ase case by Ballentine & Blecher (Ref. 4) and by de roekert and Scarlett (Ref. 5). Here, the analysis is some vhat different as it is aimed to serve a different purpose.

. Equivalent Circuit Model of a Transistor in the Common Emitter Connection

he symbols used in the equivalent circuit of Fig. 8 are s follows:

$$r_{e'} \simeq \frac{KT}{qI_{Edc}} \sim \frac{26}{I_{Edc}} \text{ ohms at T} = 290^\circ \text{ K where } I_{Edc} \text{ is in mA}$$

$r_{b'}$ = Base spreading resistance.

$$h_{fe} = \frac{\beta}{1 + j\frac{\omega}{\omega_\beta}}; \beta \triangleq \frac{\alpha}{1-\alpha}$$

f_t = Short circuit current gain bandwidth.

$\omega_\beta \triangleq (1-\alpha)\,\omega_t$
β = Low frequency short-circuit current gain.
$r_{e''}$ = Emitter body and contact resistance.
C_s = Stray capacitance from collector to base.
C'_{bc} = Capacitance from collector to base which is not directly under emitter dot. This capacitance is important in mesa type transistors.
C_c = Collector capacitance under emitter dot.

The transistor circuit model shown in Fig. 8 is too complicated to use for amplifier analysis. A simpler model is shown in Fig. 9. The neglected quantities are taken into account in an approximate way later.

$$h_{11e} = r_{b'} + \frac{R\omega_\beta}{p + \omega_\beta}$$

$$h_{21e} = h_{fe} = \frac{\beta\omega_\beta}{p + \omega_\beta}$$

$$h_{22e} = h_{12e} = 0.$$

2. Analysis of One Stage Amplifier with Emitter Feedback

The equivalent circuit of Fig. 10 will be used in this analysis. Here h parameters are useful. The h parameters of the composite circuit are:

$$\left.\begin{aligned} h'_{11e} &= h_{11e} + (h_{21e} + 1)\,Z_e \\ h'_{21e} &= h_{21e} = \frac{\beta\omega_\beta}{p + \omega_\beta},\ h'_{22} = h'_{12} = 0. \end{aligned}\right\} \quad \text{A(1)}$$

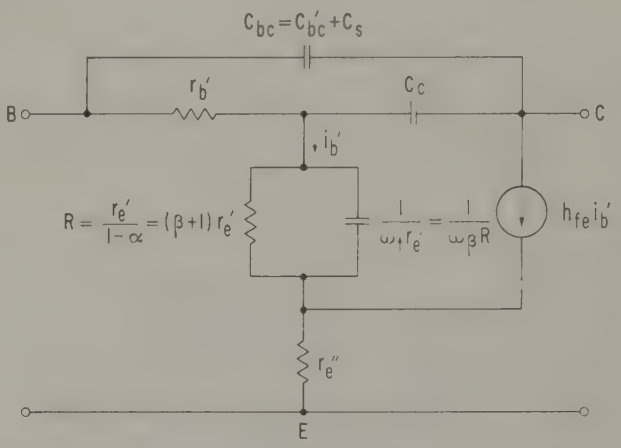


Fig. 8—Equivalent circuit of a transistor. Here collector body resistances and stray capacitances from emitter to collector and base are not shown.

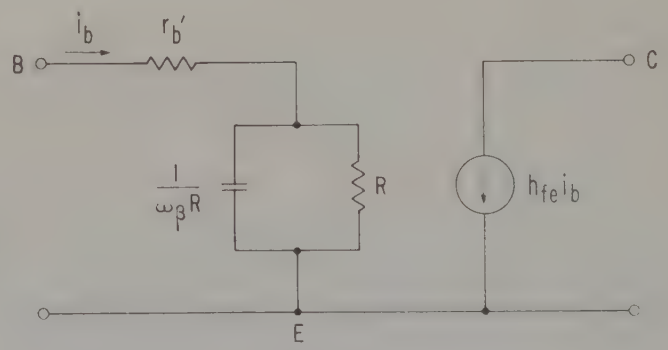


Fig. 9—Simplified model of transistor. Here C_c, C_{bc} and $r_{e''}$ are neglected.

$$\frac{e_o}{e_s} = \frac{-h'_{21}\,R_L}{h'_{11e} + R_s} \quad \text{A(2)}$$

Let $R = (\beta + 1)\ r_{e'}$ (see Fig. 10).

When $Z_e = R_e$,

$$\frac{e_o}{e_s} = \frac{-\beta\omega_\beta\,R_L}{P(R_s + r_{b'} + R_e) + \omega_\beta[R_s + R + r_{b'} + (\beta+1)\,R_e]} \quad \text{A(3)}$$

$$\text{Low frequency gain } A_{v_o} = \frac{\beta\,R_L}{R_s + R + r_{b'} + (\beta+1)\,R_e} \quad \text{A(4)}$$

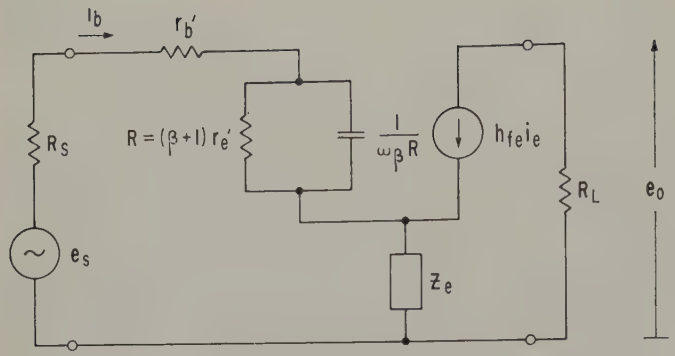


Fig. 10—One stage amplifier with emitter feedback.

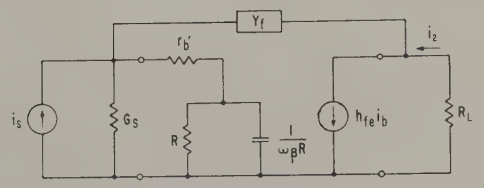


Fig. 11—Collector-to-base feedback stage.

$$\text{3 db bandwidth} = \omega_T \left[\frac{R_e + r'_e + \dfrac{R_s + r_{b'}}{(\beta + 1)}}{R_s + r_{b'} + R_e} \right] = B_v \qquad \text{A(5)}$$

When

$$Z_e = \frac{R_e \omega_e}{p + \omega_e}$$

where feedback circuit is a parallel combination of R_e and C_e and

$$\omega_e = \frac{1}{R_e C_e},$$

$$\frac{e_o}{e_s} = \frac{-\beta\, \omega_\beta\, R_L\, (p + \omega_e)}{\left\{ \begin{array}{c} p^2 (R_s + r_{b'}) + p\,[\omega_e (R_s + R_e + r_{b'}) + \omega_\beta\, (R_s + R + r_{b'})] \\ + \omega_e \omega_\beta\, [R_s + R + r_{b'} + R_e\, (\beta + 1)] \end{array} \right\}}$$

$$= \frac{k\, (p + \omega_e)}{ap^2 + bp + c} \qquad \text{A(6)}$$

When the above transfer function is driven by a step function, the time response will contain only damped exponentials which combine to give a monotonic rise to the final value provided the denominator quadratic has real roots; i.e., $b^2 \geqq 4ac$. This is a sufficient but not a necessary condition for no overshoot.

With the condition $b^2 = 4ac$, we get the value for ω_e as: using the approximation

$$\omega_e = 4B_v \left(1 - \frac{R_e}{R_s + r_{b'} + R_e} \right), \qquad \text{A(7)}$$

using the approximation
$\omega\beta\ (R_s + R + r_{b'}) \ll \omega_e\ (R_s + R_e + r_{b'})$.

This approximation will be satisfied if $B_v > 5f_\beta$ where B_v is the bandwidth with only the resistance R_e connected in the feedback.

The double pole location will lie at

$$\frac{-b}{2a} = 2B_v. \quad \text{See Eq. A(5).}$$

Now $$\frac{e_o}{e_s} = \frac{K}{a} \frac{\left[p + 4B_v \Big/ \left(\dfrac{R_e}{1 + R_s + r_{b'}} \right) \right]}{(p + 2B_v)^2}. \qquad \text{A(8)}$$

The rise-time improvement with capacitive peaking is plotted as a function of $R_e\ /\ R_s + r_{b'}$, in Fig. 12. This graph is taken from Ref. (1), where a similar type of analysis appears in the case of the shunt-peaked amplifier.

The rise-time-improvement factor η is defined as

$$\eta = \frac{\text{Rise time of the one stage amplifier with only } R_e \text{ connected in the emitter} = 2\pi \times 0.35/B_v.}{\text{Rise time of the stage with } R_e \text{ and } C_e \text{ in the feedback where } C_e \text{ is chosen for no overshoot in pulse response.}}$$

The values of η are not useful when

$$\frac{R_e}{R_s + r_{b'}} < 0.05,$$

since these values of R_e correspond to the small bandwidth case and the approximations used in the analysis are not valid.

3. Analysis of a Single Stage Amplifier with Collector-to-Base Feedback

Figure 11 is used for the purpose of this analysis. Here, y parameter representation is more useful. The parameters of the transistor including feedback are:

$$\left. \begin{array}{l} y_{11e} = \dfrac{p + \omega_\beta}{pr_{b'} + \omega_\beta\, (R + r_{b'})} + y_f \\ y_{22e} = -y_{12e} = y_f \\ y_{21e} \cong \dfrac{\beta\, \omega_\beta}{pr_{b'} + \omega_\beta\, (R + r_{b'})} \end{array} \right\} \qquad \text{A(10)}$$

When $y_f = G_f = 1/R_f$,

$$\frac{i_2}{i_s} = \frac{y_{21}\, G_L}{(y_{11} + G_s)\, (G_f + G_L) + G_f y_{21}} \qquad \text{A(11)}$$

$$= \frac{A_{io}\, B'_i}{p + B'_i} \qquad \text{A(12)}$$

where A_{io} = low frequency current gain

$$= \frac{\beta\, G_L}{(G_f + G_L)\, [1 + (G_f + G_s)\, (R + r_{b'})] + G_f \beta}. \qquad \text{A(13)}$$

B'_i = 3 db bandwidth

$$= \frac{\omega_\beta\, \beta\, G_L}{A_{io}\, (G_f + G_L)\, [1 + (G_f + G_s)\, r_{b'}]}. \qquad \text{A(14)}$$

$$\text{Current gain bandwidth} = \frac{\omega_\beta\, \beta\, G_L}{(G_f + G_L)\, [1 + (G_f + G_s)\, r_{b'}]}. \qquad \text{A(15)}$$

This is maximum when $G_s = 0$; let us consider only this case.

$$\frac{i_2}{i_s} = \frac{y_{21}\, G_L}{y_{11}\, (y_{22} + y_L) - y_{12} y_{21}}. \qquad \text{A(16)}$$

When $y_f = \dfrac{1}{Z_f} = \dfrac{1}{pL + R_f}$, i.e., inductance and resistance in series connected in the feedback, then

$$\frac{i_2}{i_s} = \frac{K'(p+\omega_f)}{p^2+Bp+C} \qquad \text{A(17)}$$

where $B = R_L\,\omega_f\,(G_f + G_L + r_{b'}\,G_L\,G_f)$

$$C = R_L\,\omega_f\omega_\beta[G_f(\beta+1) + G_L + G_L\,G_f\,(R+r_{b'})] \qquad \text{A(18)}$$

$$K' = \beta\,\omega_\beta.$$

Here the approximations used in obtaining the expressions are well satisfied if the bandwidth $B > 5f_\beta$.

The gain function [Eq. A(17)] is of the same form as in the case of emitter feedback. For no overshoot the value for

$$\omega_f = \frac{R_f}{L}$$

is given by

$$\omega_f = \frac{4\,B_i}{1+\dfrac{r_{b'}+R_L}{R_f}} \qquad \text{A(19)}$$

where B_i is the bandwidth with only resistance R_f in the feedback [A(14) with $G_s = 0$],

$$B_i = \omega_\beta\,\frac{\{(G_f+G_L)\,[1+G_f\,(R+r_{b'})]+G_f\beta\}}{(G_f+G_L)\,(1+G_f\,r_{b'})}. \qquad \text{A(20)}$$

The expression for current gain is of the form:

$$\frac{i_2}{i_s} = \frac{K'\left[p+4B_i\Big/\left(1+\dfrac{r_{b'}+R_L}{R_f}\right)\right]}{(p+2\,B_i)^2} \qquad \text{A(21)}$$

This current gain equation is in the same form as voltage gain expression [Eq. A(8)] in the emitter feedback case. The rise-time-improvement factor in this case can be defined in the same way as before and the Fig. 12 can be used except that the variable in the case is

$$\frac{r_{b'}+R_L}{R_f}.$$

4. Considerations of the Effects of C_c, C_{ob} and $r_{e''}$: (Refer to Fig. 8)

The presence of $r_{e''}$ (varies from 1 — 5 ohms depending on the type of transistor) has the effect of built-in emitter feedback in the transistor. In the case of an emitter feedback circuit without capacitive peaking, $r_{e''}$ adds to the externally connected R_e and hence the calculated value of R_e should be reduced by $r_{e''}$. In the case of capacitive peaking $r_{e''}$ is not included in peaking and the correction in the wideband case ($R_e \gg r_{e''}$) is not very important. In the collector-to-base feedback $r_{e''}$ can be taken into account by writing $R = (r_{e'} + r_{e''})\,(\beta + 1)$ instead of $r_{e'}\,(\beta + 1)$. At high frequencies C_c and C_{bc} are the primary causes of the non-unilateral characteristic of a transistor. C_{bc} varies with collector-to-base reverse bias voltage (V_{CB}); it is lower for high voltages and is independent of emitter bias current (I_E). C_c varies with V_{CB} and I_E. It decreases with higher values of V_{CB} and increases with higher values of I_E. Accounting exactly for C_c and C_{bc} in amplifier analysis is complicated. Bruun (Ref. 3) accounts for C_c quite accurately in his analysis of emitter feedback case and the resulting equations are somewhat unwieldy. An approximate way of taking into account C_c and C_{bc} is by adding a Miller type capacitance across the emitter diffusion capacitance in the equivalent circuit and modify the value of ω_β *or* ω_T. Such a correction is dependent on stage voltage gain. For video amplifier work a fixed correction is satisfactory but may be useless in the narrow pass band amplifier case. The type of correction to ω_β *or* ω_T is to reduce these quantities by a factor

$$\frac{1}{1+K\omega_T\,R_L\,C}$$

which is always less than unity.

In this expression, $C = C_c + C_{bc}$ and K is a constant depending among other things upon the type of feedback used. In the emitter feedback case the effect of C_c and C_{bc} is more pronounced. The value of K will vary with different types of transistors and for the 2N706 ($C_c \cong 1.5$ *pf*, $C_{bc} \simeq 3$ *pf*, $r_{b'} \cong 70$ ohms) with a 50 ohm load and in the range of bandwidths under consideration, $K = 0.7$ for the collector-to-base feedback case and $K = 1.0$ for the emitter feedback case where found to be useful in designing amplifiers. Now an effective beta cutoff frequency $\omega_{\beta'}$, should be used in all the above derived equations in place of ω_β where

$$\omega_{\beta'} = \frac{\omega_\beta}{1+K\omega_T\,R_L\,C} \qquad \text{A(22)}$$

Similarly, ω_T should be replaced by $\omega_{T'}$ where

$$\omega_{T'} = (\beta+1)\,\omega_{\beta'} \qquad \text{(A23)}$$

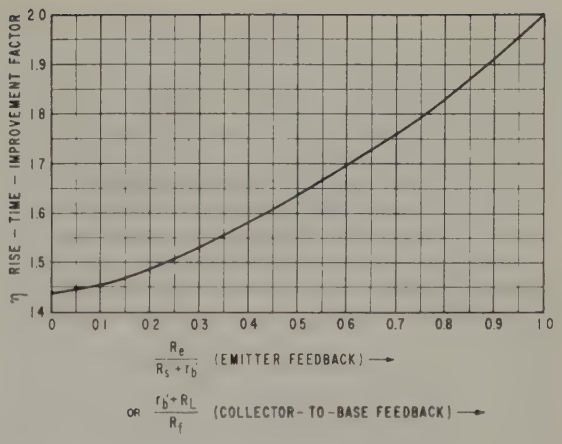


Fig. 12—Rise time improvement vs. $R_e/(R_s + r_{b'})$

Acknowledgement

The author expresses his thanks to Professor R. M. Scarlett of Stanford University and to his colleagues at Fairchild Semiconductor Corporation, Messrs. Grinich, Beneteau and Lane.

References

1. E. E. 221 course class notes, Stanford University, Stanford, California. To be published as a text book under the authorship of J. M. Pettit.
2. V. H. Grinich, "Stagger-Tuned Transistor Video Amplifiers," *Trans IRE*, vol. BTR-2, October 1956.
3. G. Bruun, "Common-Emitter Transistor Video Amplifiers," *Proc. IRE*, vol. 44, November 1956.
4. W. E. Ballentine and F. H. Blecher, "Broadband Transistor Video Circuits," 1959 Solid State Circuit Conference Digest.
5. J. C. de Broekert and R. M. Scarlett, "A Transistor Amplifier with 100 mc Bandwidth," Tech Rep No. 514-1, Stanford Electronics Laboratories, Stanford University, California.
6. J. Kabell and V. H. Grinich, "Zener Diode Circuits for Stable Transistor Biasing," Fairchild Technical Paper No. 8.
7. P. J. Beneteau and J. A. MacIntosh, "A 2 Nanosecond Video Amplifier," Fairchild Semiconductor Corp. Application Note APP-38.

A Monostable Transistor Circuit For High-Ratio Frequency Division And Generation Of Short Pulses

Part 1

WERNER STEIGER*

A monostable circuit is presented which uses two complementary transistors and features timing compensated to be independent of the transistor current gains; short recovery time which permits very asymmetrical operation; relative insensitivity to loading and to trigger amplitude variations. Two configurations are analyzed in detail and expressions are given for the timing period, its supply voltage dependence and its temperature dependence, including the influence of the semiconductor reverse currents and of various trigger arrangements. The final part of the timing from the instant the circuit becomes active to the regenerative switching-on, is treated separately; and approximations, relating it to the circuit and transistor parameters, are developed. It is shown that this timing portion and the main timing have opposite current-gain dependence. An approximate condition for perfect compensation is derived. As a design example, a frequency divider for 10mc input was built with silicon mesa transistors. Experimental results are included.

FREQUENCY DIVIDERS may be grouped into monostable circuits and circuits using counting techniques. If the frequency to be divided is reasonably constant, one has the choice between the two types. In general, monostable dividers are more economical, since a certain division ratio requires fewer stages. The ratio obtainable with monostable multivibrators is limited by the ratio of the timing time constant to the recovery time constant. The conventional two-transistor circuit is not very capable in this respect.

Circuit Description

The monostable circuit to be presented here uses two complementary transistors and is capable of very asymmetrical operation. Therefore, it is equally suited for generating short pulses or for use as a high-ratio frequency divider.

The circuit shown in Fig. 1 was built with silicon mesa transistors SXG7 and SXG8, with alpha cutoff frequencies in the order of 200 megacycles, and produced pulses as short as 0.1 microseconds. Division by ten with ±5% frequency margin was still possible at 10 mc. The diodes were of the fast recovery types SA5 and SA1-2.

The circuit is in its stable state when both transistors are conducting. The timing capacitor C is then charged to almost the supply voltage E. Under these conditions the trigger gate D_3-D_4 can accept a negative trigger pulse and route it to the base of Q_1. This turns off both transistors regeneratively. The voltage at the base of Q_2 shoots up to almost $2E$, and C starts to discharge through R and R_1. Breakdown of the emitter-base junction is prevented by D_2. The timing terminates soon after the emitter-base junction of Q_2 reaches forward conduction, namely at the moment when the loop gain of the circuit exceeds unity, causing both transistors to turn on by regeneration. The recovery time is very short since the two transistors switch the timing capacitor C directly to the supply voltage to be recharged, (typically 20 nanoseconds in our case). Diode D_1 routes most of the current surge through the collector of Q_2. Only a fraction flows into the base, keeping Q_2 switched on. This prevents saturation of Q_2, which not only results in faster circuit recovery, but, for the following reason, also is important for the temperature stability of timing. If Q_2 is in saturation when switching is initiated at Q_1, the timing capacitor C loses the charge necessary to sweep out the excess carriers. As the storage is directly related to the current gain, the timing may become quite temperature dependent.

Transistor Q_1, on the other hand, is permitted to reach saturation. The circuit is designed for transistors

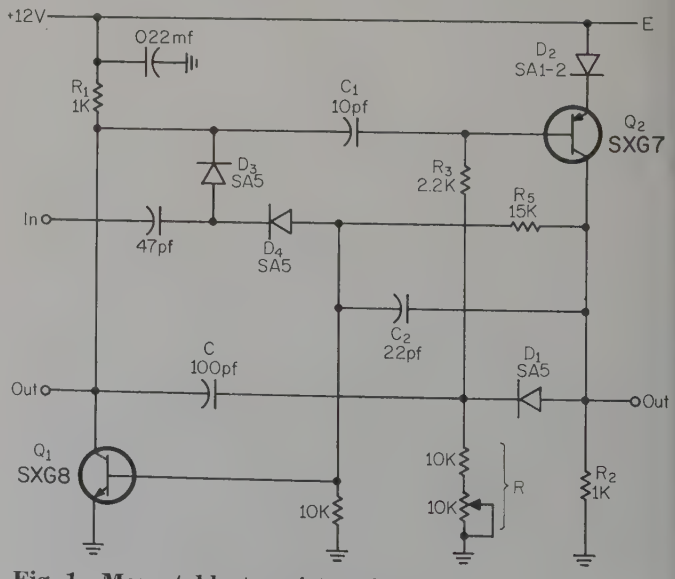


Fig. 1—Monostable transistor circuit with short recovery time.

*Hughes Aircraft Company, Fullerton, California.

with a minimum direct-current-gain of about 25. Since the trigger pulse can enter the circuit only during the short "on" period, its amplitude does not influence the timing.

Figures 2 and 3 show two basic arrangements and the notation used in the following analysis. They differ only in the location of diode D_2 and the addition of a resistor R_4 which provides an external path for the collector reverse current of Q_2. (R_4 could be connected directly from base to emitter, but then any changes of V_{B2} would appear multiplied by $(1 + R_3/R_4)$.)

As far as the semiconductors are concerned, the temperature influences the timing in two ways: through the changing voltage drop across forward biased junctions, and the varying reverse current through backward biased junctions. While both configurations are comparable as to the first influence, "B" may be superior with respect to the latter since the leakage which speeds up the discharge of C, is now determined only by D_1 and D_2, and no longer by Q_2. Circuit B can be advantageous in the case of germanium transistors, particularly for high-gain units, since the separate base return R_4 makes a high value of the timing resistor R practical.

Alternately, the switching may be initiated by a positive trigger at the base of Q_2 (trigger methods II and III shown in Fig. 4). However, if the circuit is heavily overdriven on this side, a positive spike will be superimposed on the timing waveform, increasing the delay. This can be corrected by using configuration B and a diode across the emitter-base junction of Q_2. While the diode from collector to input capacitor cannot be replaced by a resistor when triggering at Q_1 (because the fraction of the input signal appearing at the collector would ride on the timing waveform), it is permissible in this case (method III), provided the time constant of input capacity and steering resistor is small enough.

The polarity of all the signals can of course be inverted by exchanging the two transistors and reversing all diodes and the power supply.

A useful feature of this circuit type is that, due to the fast recovery of the timing elements, both collectors furnish equally good waveforms.

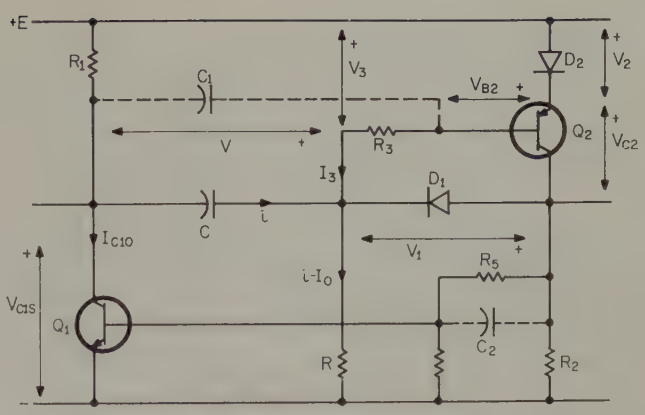


Fig. 2—Configuration "A".

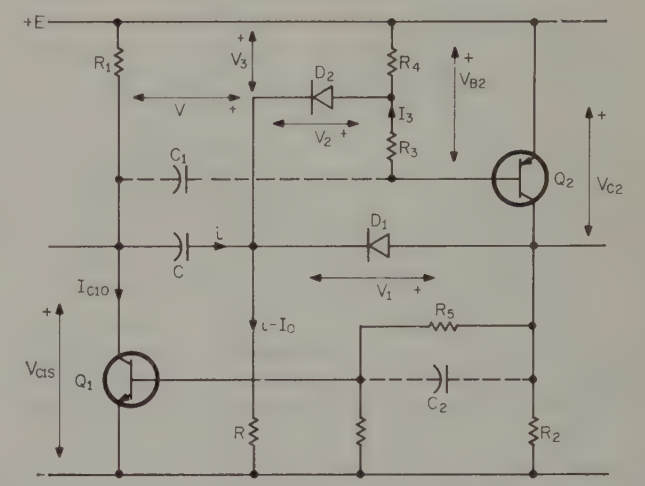


Fig. 3—Configuration "B".

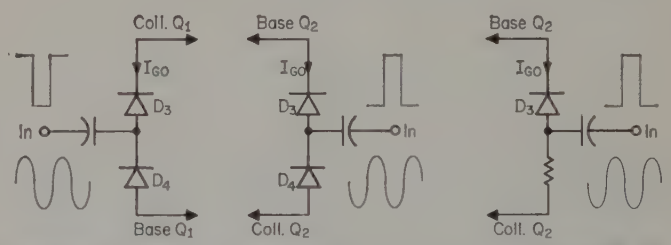


Fig. 4—Trigger arrangements.

Analysis

The time τ expiring between application of the trigger pulse and the generation of the output pulse is composed of three separate portions:

$$\tau = \tau_s + \tau_d + \tau_r. \qquad (1)$$

τ_s is the time required to switch off the circuit. It is mainly storage time of Q_1, and therefore also dependent on trigger waveform and amplitude. However, τ_s can easily be kept quite small (typically 40 nanoseconds in our case), and also reasonably constant as long as the trigger amplitude is well above the necessary minimum.

Much more significant, and to be analyzed in this article are the delay time τ_d and the regeneration time τ_r.

Delay Time τ_d

We define τ_d as the time during which the ramp runs down without base current in Q_2.

The configurations in Fig. 2 and 3 have been analyzed, including the influence of reverse currents in the various trigger arrangements (Fig. 4). The results for the delay time are given in Table I. The derivatives of the delay time with respect to supply voltage and temperature are shown in Table II. The change of the reverse currents can be estimated from Fig. 5.

The notation follows the included list of symbols (see pp. 29, 30) and Figs. 2 and 3.

During the "on" period we can write

$$V_{on} = E - V_1 - V_2 - V_{C1S} - V_{C2} \qquad (2A)$$

for configuration "A" and

$$V_{on} = E - V_1 - V_{C1S} - V_{C2} \qquad (2B)$$

for configuration "B".

During the timing period, where the transistors are off, we have:

$$E - R_1 (i + I_{C10}) + V_{off} - R (i - I_0) = 0, \qquad (3)$$

$$E - V_{3\,off} - R (i - I_0) = 0, \qquad (4)$$

$$V_{off} = V_{on} - \frac{1}{C} \int_0^t i\, dt. \qquad (5)$$

Eq. (3) and (5) yield:

$$i = i_0 \exp\left[- \frac{t}{C (R + R_1)} \right]. \qquad (6)$$

At $t = 0$, V_{off} in (3) can be replaced by V_{on} [(2A) or (2B)]:

$$i_0 = \frac{E + V_{on} + RI_0 - R_1 I_{C1}}{R + R_1}. \qquad (7)$$

We defined the delay as ending at the time the base current of Q_2 starts to be positive, that is, when

$$V_{3\,off} = V_2 + V_{B2} + R_3 I_3 \qquad (8)$$

(where I_3 may differ from zero for trigger methods II and III).

Thus, the expressions (4), (6), (7) and (8) furnish for the delay time:

$$\tau_d = C(R+R_1) \ln \frac{R\,(2E - V_S + RI_0 - R_1 I_{C1})}{(R+R_1)\,(E - V_2 - V_{B2} + RI_0 - R_3 I_3)} \qquad (9)$$

In Table I, this result is applied to either configuration in combination with any of the trigger circuits. The fact, that in case "B" diode D_2 starts to conduct a little earlier due to the presence of R_4, contributes a negligible difference and is neglected.

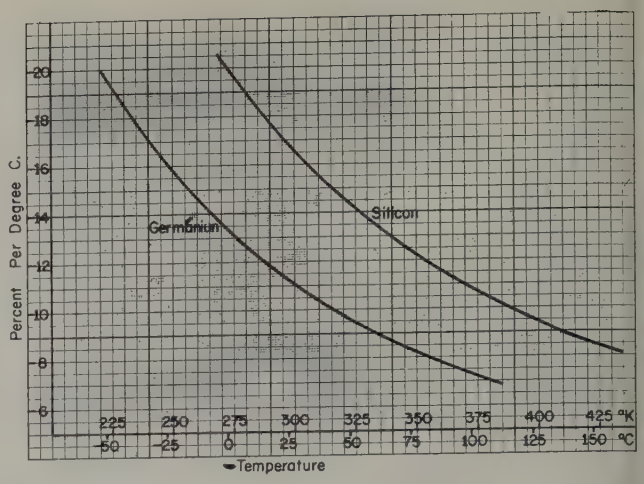


Fig. 5—Relative change per degree of semiconductor reverse currents and [intrinsic carrier density]^2.

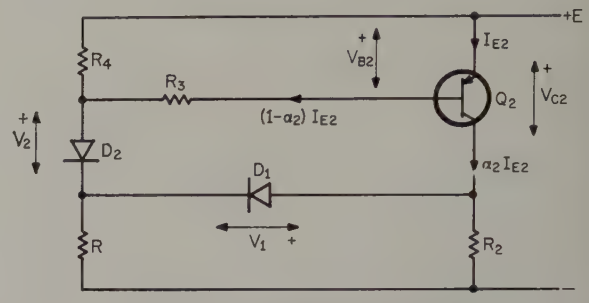


Fig. 6—Q_2 during conduction.

It remains to find the collector voltage V_{C2} of transistor Q_2 during conduction. From Fig. 6 which shows the conditions in configuration "B", we can write:

$$I_{E2} = (E - V_{C2})(G + G_2) - V_1 (G + G_4) - (V_{C2} - V_2)\, G_4, \qquad (10)$$

$$V_{C2} = V_{B2} + V_2 - V_1 + (1 - \alpha_2)\, R_3 I_{E2}. \qquad (11)$$

Hence

$$V_{C2} = \frac{V_{B2} + V_2 - V_1 + (1-\alpha_2)\, R_3 \left[E\,(G+G_2) - V_1\,(G+G_4) + V_2 G_4 \right]}{1 + (1-\alpha_2)\, R_3\,(G + G_2 + G_4)}. \qquad (12B)$$

TABLE I — Delay Time

Basic → / Trigger Circuit ↓	A	B
	$\tau_d = C_t\,(R + R_1) \ln \dfrac{R\,(2E - V_S + RI_0 - R_1 I_{C1})}{(R + R_1)\,(E - V_2 - V_{B2} + RI_0 - R_3 I_3)}$	
	$C_t = C + C_1$	$C_t = C$
	$V_S = V_1 + V_2 + V_{C1S} + V_{C2}$	$V_S = V_1 + V_{C1S} + V_{C2}$
I	$I_0 = I_{10} + I_{C20} + (I_{20}$ or $I_{E20})$	$I_0 = I_{10} + I_{20}$
	$I_{C1} = I_{C10} + I_{G0}$	
	$I_3 = 0$	
II, III	$I_0 = I_{10} + I_{C20} + (I_{20}$ or $I_{E20}) + I_{G0}$	$I_0 = I_{10} + I_{20}$
	$I_{C1} = I_{C10}$	
	$I_3 = -I_{G0}$	
	(or = whichever smaller)	

With V_2 and G_4 equal to zero, V_{C2} for configuration "A" is obtained:

$$V_{C2} = \frac{V_{B2} - V_1 + (1-\alpha_2)\, R_3\, [E\,(G+G_2) - V_1\, G]}{1 + (1-\alpha_2)\, R_3\, (G+G_2)}. \quad (12A)$$

For $V_{B2} \cong V_1$ and $E >> V_1$ (circuit A):

$$V_{C2} \simeq \frac{(1-\alpha_2)\, R_3\, E\, (G+G_2)}{1 + (1-\alpha_2)\, R_3\, (G+G_2)}. \quad (13A)$$

For $V_1 \cong V_2$ and $E >> V_1$ (circuit B):

$$V_{C2} \simeq \frac{V_{B2} + (1-\alpha_2)\, R_3\, E\, (G+G_2)}{1 + (1-\alpha_2)\, R_3\, (G+G_2+G_4)}. \quad (13B)$$

The voltage and temperature dependence (Table II) has been calculated for

$$V_S - RI_0 + R_1 I_{C1} \ll 2E,$$

$$V_2 + V_{B2} - RI_0 + R_3 I_3 \ll E.$$

With Eq. (9) and (13A), the derivative with respect to the supply voltage becomes

$$\frac{\delta\tau_d}{\delta E} = \frac{C\,(R+R_1)}{2\,E^2}\,(V_{C1S} - 2\,V_F + V_0). \quad (14)$$

The same result can be derived from Eq. (9) and (13B) for circuit "B", under the restriction that

$$(1-\alpha_2)\, R_3\, (G+G_2+G_4) \ll 1,$$

and changing the meaning of V_F and V_0 as shown in Table II.

The rate of change of τ_d with temperature represents the influence of the semiconductors only. Also, the variations in semiconductor resistivity with temperature have been neglected (the temperature coefficient may be of either sign, depending upon doping and temperature). Then, the rate of change of the voltage across forward biased junctions can be approximated by[1]

$$\frac{\delta V_F}{\delta T} = \frac{V_F}{T} - \psi \frac{kT}{q}, \quad (15)$$

which is about minus 2.5 millivolts per degree centigrade for both germanium and silicon. The collector saturation voltage is considered as the voltage difference of the two junctions in the transistor, both forward biased. Its temperature dependence therefore, being of second order, is neglected.

It follows from Eq. (13A) that

$$\frac{\delta V_{C2}}{\delta T} = -\frac{R_3\,(G+G_2)\,(E-V_{C2})}{1 + (1-\alpha_2)\, R_3\, (G+G_2)} \left(\frac{\delta\alpha_2}{\delta T}\right), \quad (16A)$$

and from (13B) that

$$\frac{\delta V_{C2}}{\delta T} = \frac{(\delta V_{B2}/\delta T) - R_3[E(G+G_2) - V_{C2}(G+G_2+G_4)](\delta\alpha_2/\delta T)}{1 + (1-\alpha_2)\, R_3\, (G+G_2+G_4)}. \quad (16B)$$

If the V_{C2}-terms in Eq. (16A) and (B) are much smaller than the E-terms, and if the denominators are close to unity, we can write for the temperature dependence of both configurations:

$$\frac{\delta\tau_d}{\delta T} \simeq \frac{C\,(R+R_1)}{2E}\left[2\,\frac{\delta V_F}{\delta T} + ER_3\,(G+G_2)\,\frac{\delta\alpha_2}{\delta T} - \psi\, V_0\right]. \quad (17)$$

The composition of V_F and V_0 for the various circuit arrangements again follows Table II.

Regeneration Time τ_r

We define τ_r as the time expiring between the start of base current flow and the regenerative switching-on of the circuit.

In the following analysis, we shall consider the transistors as charge-controlled devices.[2] One of the advantages of this method is that the combined influence of cutoff frequency and collector capacity enters the calculations in the form of a single parameter which, in addition, is very easily measured.

The equivalent circuit is given in Figure 7. For the sake of a general solution, the speedup capacitors and the fact that Q_1 (because its emitter-base potential has first to be overcome) starts to conduct a little later than Q_2, are disregarded. As these effects counteract,

TABLE II — Voltage and Temperature Dependence of Delay Time

Basic → / Trigger ↓ Circuit	A	B
	$\frac{\delta\tau_d}{\delta E} = \frac{C_t\,(R+R_1)}{2E^2}\,(V_{C1S} - 2\,V_F + V_0)$	
	$\frac{\delta\tau_d}{\delta T} = \frac{C_t\,(R+R_1)}{2\,E}\left[2\,\frac{\delta V_F}{\delta T} + ER_3\,(G+G_2)\,\frac{\delta\alpha_2}{\delta T} - \psi V_0\right]$	
	$C_t = C + C_1$	$C_t = C$
	$2\,V_F = 2\,V_{B2} + V_2 - V_1$	$2\,V_F = 2\,V_2 + V_{B2} - V_1$
I	$V_0 = RI_0 + R_1\,(I_{C10} + I_{G0})$	
II, III	$V_0 = R\,(I_0 + I_{G0}) + R_1 I_{C10} + 2R_3 I_{G0}$	$V_0 = RI_0 + R_1\,I_{C10} + 2R_3 I_{G0}$

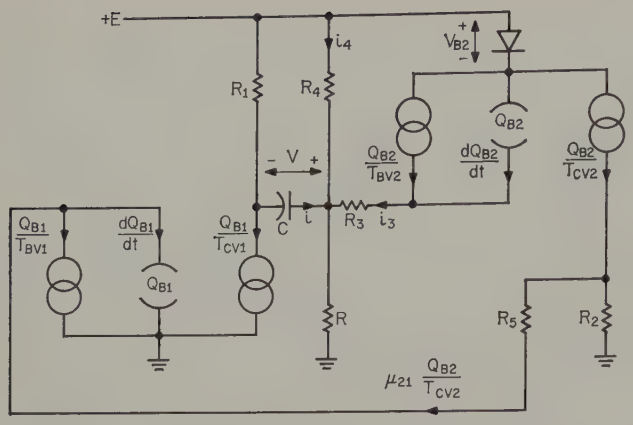


Fig. 7—Equivalent circuit to determine τ_r.

and the main influence of the speedup capacitors occurs usually during the regenerative switching, the result of this analysis is still quite useful. Also, since τ_r is in general only a fraction of τ_d, the reverse currents are neglected in this part.

The first step is to find the base current i_3 (t) of Q_2 prior to regeneration. If we open the feedback loop and call $t = 0$ when base current sets in, we can write for Fig. 7:

$$i_4R_4 + v - i_1R_1 = 0 \tag{18}$$

$$V_{B2} + i_3R_3 - i_4R_4 = 0 \tag{19}$$

$$i_4R_4 + (i+i_3+i_4)\,R = E \tag{20}$$

$$v = V_{C0} - \frac{1}{C}\int_0^t i\,dt \tag{21}$$

From these equations, the solution for i_3 is:

$$i_3 = i_{3\infty}\left[1 - \exp\left(-\frac{t}{T_r}\right)\right], \tag{22}$$

with

$$i_{3\infty} = \frac{E - V_{B2}\,(1+RG_4)}{R + R_3\,(1+RG_4)} \tag{23}$$

and

$$T_r = C\left(R_1 + \frac{1}{G + G_3 + G_4}\right). \tag{24}$$

i_3 is amplified in both transistors and causes a collector current i_{c1} in Q_1. Regeneration will occur as soon as the small-signal current gain of the complete loop exceeds unity:

$$\mu_{12}\frac{di_{C1}}{di_3} = \mu_{12}\frac{di_{C1}/dt}{di_3/dt} = 1, \tag{25}$$

where μ_{12} is the (small signal) current transfer between Q_1 and Q_2.

It is seen in Fig. 7 that:

$$\frac{dQ_{B2}}{dt} + \frac{Q_{B2}}{T_{BV2}} = i_3, \tag{26}$$

$$\frac{dQ_{B1}}{dt} + \frac{Q_{B1}}{T_{BV1}} = \mu_{21}\frac{Q_{B2}}{T_{CV2}}, \tag{27}$$

where μ_{21} is the current transfer between Q_2 and Q_1

$$(\mu_{12}\mu_{21})^{-1} \simeq (1 + R_5G_2)\,[1 + (R_3+Z_{b2})\,(G+G_1+G_4)] \tag{28}$$

with

$$Z_{b2} \simeq \frac{kT\,T_{BV2}}{qI_E'_2T_{CV2}} \tag{29}$$

as a pessimistic approximation.

From Eq. (22), (26) and (27), the Laplace transform of i_{c1} is

$$i_{C1}(p) = \frac{Q_{B1}(p)}{T_{CV1}} = \frac{\mu_{21}\,i_{3\infty}}{T_r\,T_{CV1}\,T_{CV2}}\left[p\left(p+\frac{1}{T_r}\right)\left(p+\frac{1}{T_{BV1}}\right)\left(p+\frac{1}{T_{BV2}}\right)\right]^{-1}. \tag{30}$$

Since we are interested in di_{c1}/dt we look for the inverse transform of pi_{c1} (p). We abbreviate:

$$\frac{T_r}{T_{BV1}} = b_1, \qquad \frac{T_r}{T_{BV2}} = b_2. \tag{31}$$

Three cases have to be considered:

(a) $T_r \neq T_{BV1} \neq T_{BV2}$:

$$\frac{di_{C1}}{dt} = \frac{\mu_{21}\,i_{3\infty}\,T_r}{T_{CV1}\,T_{CV2}}\left[\frac{\exp\,(-t/T_r)}{(b_1-1)\,(b_2-1)} + \frac{\exp\,(-b_1\,t/T_r)}{(b_1-1)\,(b_1-b_2)} + \frac{\exp\,(-b_2\,t/T_r)}{(b_2-1)\,(b_2-b_1)}\right] \tag{32a}$$

(b) $T_r \neq T_{BV1} = T_{BV2} = T_{BV}$:

$$\frac{di_{C1}}{dt} = \frac{\mu_{21}\,i_{3\infty}}{T_{CV1}\,T_{CV2}}\cdot\frac{T_r\exp\,(-t/T_r) - [T_r+(b-1)t]\exp\,(-bt/T_r)}{(b-1)^2} \tag{32b}$$

(c) $T_r = T_{BV1} = T_{BV2}$:

$$\frac{di_{C1}}{dt} = \frac{\mu_{21}\,i_{3\infty}\,t^2}{2\,T_r\,T_{CV1}\,T_{CV2}}\exp\left(-\frac{t}{T_r}\right). \tag{32c}$$

(To be continued)

Symbols

E	Supply voltage.
v	Voltage across timing capacitor.
V_0	A combination of voltage drops by reverse currents.
V_1, V_2	Forward drop at D_1, D_2.
V_{B2}	Forward emitter-base drop of Q_2.
V_{C1S}	Saturation voltage of Q_1.
V_{C2}	"on" collector voltage of Q_2.

V_F	Forward drop of a junction.
V_S	A combination of voltages during the "on" period.
i	Current through timing capacitor.
i_3	Current in R_3 during τ_r.
i_{c1}	Collector current of Q_1 during τ_r.
I_0, I_{C1}	Combinations of reverse currents.
I_{10}, I_{20}	Reverse currents of D_1, D_2.
I_3	Current in R_3 at the end of τ_d.
I_{C10}	Reverse collector-emitter current of Q_1.
I_{C20}, I_{E20}	Reverse collector-base and emitter-base currents of Q_2.
I_{E2}	"on" current of Q_2.
$I_{E'2}$	Current of Q_2 when regeneration starts.
I_{G0}	Reverse diode current of the trigger gate.
b	(normalized base time constant)$^{-1}$.
G	$1/R$ throughout.
k	Boltzmann's constant.
q	| electron charge |.
Q_B	Base charge.
t	Time.
T	Absolute temperature, °K.
T_{BV}	Base time constant for varying collector voltage.
T_{CV}	Collector time constant for varying collector voltage.
T_r	Circuit time constant during τ_r.
x	Normalized regeneration time.
Z_{b2}	Small-signal input impedance of Q_2.
α	d-c common-base current-gain.
$\beta_{2\,on}$	d-c common-emitter current-gain when Q_2 carries its maximum current.
β_{reg}	d-c common-emitter current-gain when regeneration starts.
ξ, η	Auxiliary parameters.
μ_{12}, μ_{21}	Current transfer between transistors.
ψ	Relative change per degree of carrier densities in intrinsic semiconductors, and of reverse currents.
τ	Total timing period.
τ_d	Delay time.
τ_r	Regeneration time.

References

1. W. Steiger, "A Transistor Temperature Analysis and its Application to Differential Amplifiers," *IRE Transactions on Instrumentation*, December 1959.
2. R. Beaufoy and J. Sparkes, "The Junction Transistor as a Charge-controlled Device," *A.T.E. Journal*, Vol. 13, No. 4, 1957.

Gold Alloying to Germanium, Silicon and Aluminum-Silicon Eutectic Surfaces†

L. BERNSTEIN*

Part 2

Alloying To Al-Si Eutectic Surfaces

Early investigators[19] encountered much difficulty in producing bonds to Al-Si surfaces. As previously mentioned, gold alloying repeatedly produced a deleterious purple phase.

When a major development became handicapped by this malfunction to the degree that it was dubbed the "purple plague," a serious program of investigation was instituted.

Reference to the literature disclosed that Zintl[20] had remarked upon the high heat of formation and "remarkable color" of $AuAl_2$. A year later, Coffinberry[21] reported formation of a brittle purple phase which he identified as $AuAl_2$. His measurements showed it to have a calcium fluoride type structure with a = 5.9868Å. Both had been anticipated by West[22] who, in 1934, reported the distance between the gold and the aluminum atoms to be 2.58Å, appreciable less than the sum of the atomic radii (2.87Å).

With a clearer picture of the possible identity of the "purple plague" at hand, a series of synthesis was set up. Wire or preforms of pure gold, pure gold with added dopants, Au-Si, Au-Ge, and Au-Sn were alloyed onto Al-Si eutectic at temperatures in excess of 400°C. In every case, metallographic sections disclosed the presence of the "purple plague", as well as a second "goldish" phase, along with the original Au and Al-Si phases. X-ray diffraction and spectrographic analysis identified the new phases as $AuAl_2$ and Au_2Al, respectively.

For a better look at these compounds, and to isolate them from other constituents, they were prepared from the elements.

Stoichiometric proportions of pure gold and aluminum (99.999% or better) to make $AuAl_2$ and Au_2Al were mixed, placed in quartz capsules which were evacuated, sealed and then heated. At temperatures below the melting point of aluminum (660°C), heating for period up to 48 hours produced no visible re-

†Presented at the Electrochemical Society S. C. Symposium, Chicago, May 1960.

*Now Director of Research and Development, Alloys Unlimited, Inc. A portion of this work was done by the author while with Hughes Semiconductor Products.

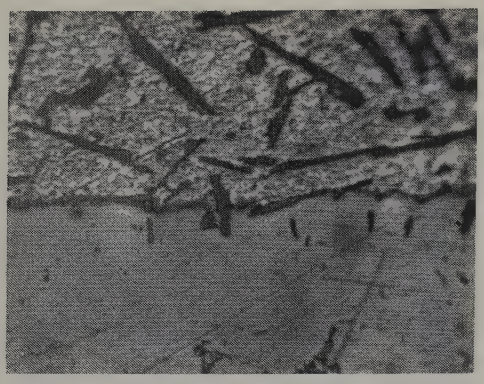


Fig. 9—Al-Si bond to Au at 425°C for 1 minute. (From a 900 X photomicrograph)

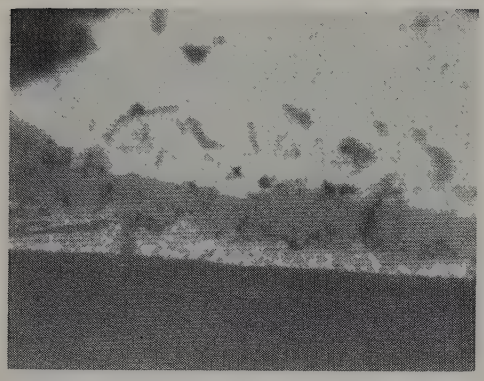


Fig. 10—Al-Si bond to Au at 450°C for 1 hour. (From a 900 X photomicrograph)

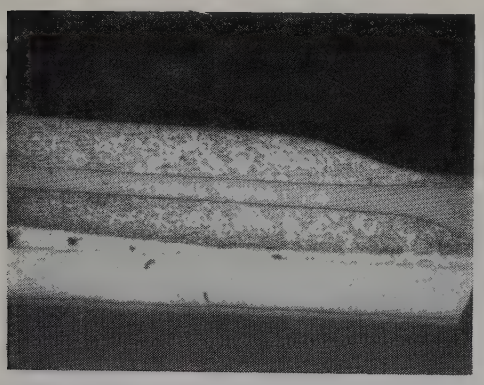


Fig. 11—Typical bond formed at 500°C for 1 minute. (From a 50 X photomicrograph)

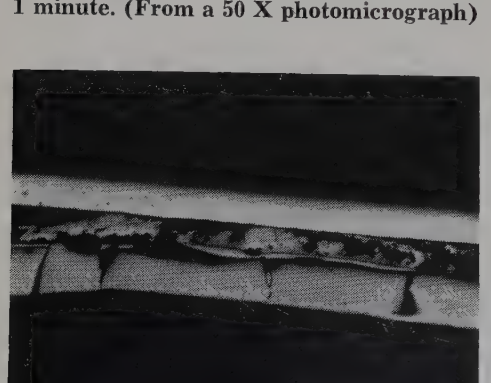


Fig. 12—Fractured bond formed at 525°C for 1 minute. (From a 40 X photomicrograph)

action. Both evacuated and oxide free capsules were then heated to 1100°C for 24 hours, slow-cooled and the samples removed for future measurements. The high aluminum mixture was predominantly purple and the other "goldish."

It is seen that elevated temperatures are required to produce the gold-aluminum alloys from the elements. Examination of the gold-aluminum phase diagram[23] indicates no possible $AuAl_2$ formation below 625°C. A liquid phase which would permit mixing of Au and Al for compound formation during electrode attachments between Au and Al-Si eutectic would not be expected at any temperature below the eutectic melting point at 577°C. It was, therefore, interesting to find the "purple plague" was actually produced at temperatures as low as 425°C. No bond was successfully formed below 425°C. This was true so long as Au, Al and Si only were present. Fig. 9 shows the formation of the thin $AuAl_2$ film at this low temperature. At temperatures of up to 500°C for *one minute* there was no appreciable increase in the amount of $AuAl_2$ formation.

Allowing the units to soak at 425-450°C for one hour, however, increased the amount of purple phase formation (Fig. 10) tremendously. At 525°C its formation is excessive and practically spontaneous. A typical bond formed at 500°C is shown in Fig. 11. At elevated temperatures or longer soaking times at lower temperatures, bonds formed typically appear as shown in Fig. 12. The interface is porous and non-continuous with resultant cracking of the silicon.

The mechanism for these reactions is believed to be as follows: In the three component Au-Al-Si system there can exist a liquid phase above 370°C (Au-Si eutectic temperature). This liquid containing gold and silicon can dissolve aluminum, thereby raising its melting point and freezing, or form a still lower melting ternary eutectic. In either case, if we consider non-equilibrium conditions, both gold-aluminum compounds can form. Evidence of the solubility of Si in $AuAl_2$ has been found by X-ray diffraction and spectrographic analysis. In addition Si dispersed both in the purple and the goldish phases in the course of electrode attachment has been detected in a metallographic section. This silicon in contact with more gold at temperatures above 370°C produces more liquid, thereby continuing the cycle until equilibrium is reached or the reaction arrested by lowering the temperature.

Generally speaking, the presence of the purple $AuAl_2$ as a *thin film* impairs neither the mechanical strength nor the electrical properties of semiconductor devices when operated at room temperatures and low current levels. There is reason to believe, however, that some devices operating at high temperatures and/or current levels may be adversely affected electrically by the presence of even a thin film. The sensitivity of the metallurgical reactions to time, the co-existence of the two gold-aluminum compounds, and the presence of the five phases in this three com-

ponent system all point out the non-equilibrium conditions under which this attachment is normally made.

Although $AuAl_2$ appears quite dense in ingot form, its behavior in electrode attachment is shown in Fig. 12. Another example showing its typical "eruptive" nature of attachment can be seen in Fig. 13 for small area contact.

Seeking a basis for this behavior, thermal expansion curves (Fig. 14) were determined for $AuAl_2$, Au_2Al, Si and the following eutectics: Au-Sn, Au-Ge, Au-Si, and Al-Si.

Among these thermal expansion curves, that for $AuAl_2$ is noteworthy because of the violent increase in expansion rate above 300°C.

The "hooks" in the expansion curves for gold-tin and Au-Al are possibly due to allotropic transformation, crystallographic rearrangement or just plain non-homogeneous alloying. In the case of the gold-tin however, numerous measurements have shown a departure from linearity in the curve between 150 and 250°C. It is believed that this condition causes serious cracking problems when alloying directly to Si, although not to Al-Si eutectic.

Because of the great differences between the expansion properties of Al-Si and Si, junctions formed by alloy fusion sometimes produce cracking of the silicon. By carefully controlling the junction geometries, thickness ratios of materials and cooling cycle, the danger of cracking or bowing, for that matter, can be completely eliminated. None of the units used in this study showed any evidence of cracking in junction formation.

Of all the alloys studied, the Au-Sn alloyed to the Al-Si most easily. No agitation and/or flux was required and, in addition, atmospheric conditions were least critical. Sound bonds were made even in non-reducing (although inert) atmospheres with dew points as high as +30°F. The Au, Au-Ge, and Au-Si alloying conditions required reducing atmospheres, lower dew points, and in general some weight to overcome surface tension and insure wetting during bonding. Table I shows alloying conditions inherent in producing good bonds.

TABLE 1

Alloying Conditions for Producing Good Bonds

Alloy	% Au	M. P. °C.	Temp. Range in °C Excess $AuAl_2$ Formation	Temp. Range in °C Good Alloy Bonding
Pure Au	100	1063	525-550	425-500
Au-Si	94	370	525-550	400-500
Au-Ge	88	356	425-450	400-425
Au-Sn	80	280	410-425	300-400

In the quaternary systems, with either Sn or Ge present in addition to the Au, Al and Si, evidently enough liquid phase is present to produce substantial

Fig. 13—Typical eruptive nature of attachment with $AuAl_2$ formation in small area contact. (From a 100 X photomicrograph)

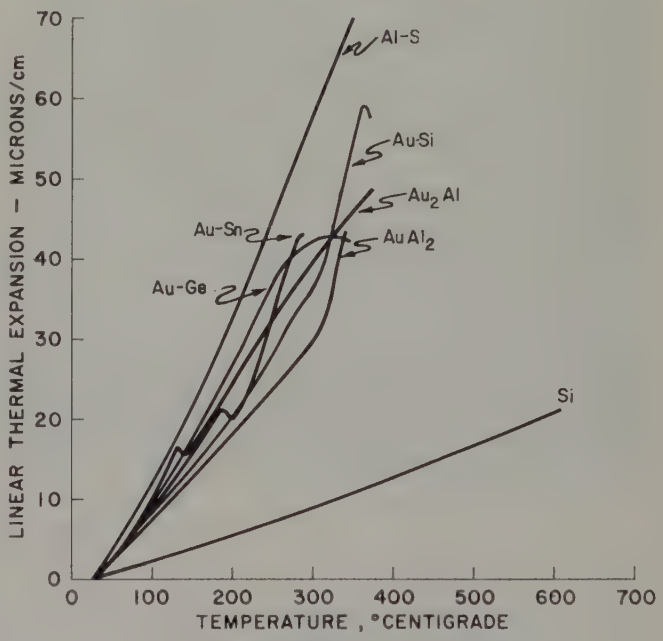


Fig. 14—Thermal Expansion Curves.

amounts of $AuAl_2$ at approximately 100°C lower than in the ternary system.

In order to fabricate semiconductor devices, one must also provide an electrode attachment to the alloyed surface. If this is done as a two-step process by first melting the chosen gold eutectic on the Al-Si surface, and then inserting a suitable wire material into the molten pool, no problem is usually encountered. If this is attempted as a one step operation, the addition of a suitable electrode wire complicates the wetting problems encountered. The problem was explored further for the Au-Sn system.

At temperatures greater than 280°C a liquid phase is sandwiched between two solid phases. Without the wire material, the Au-Sn wets the Al-Si well. When the sandwich condition exists, the surface energy relationships are such as to direct wetting toward the Au-Sn wire interface and away from the Au-Sn,

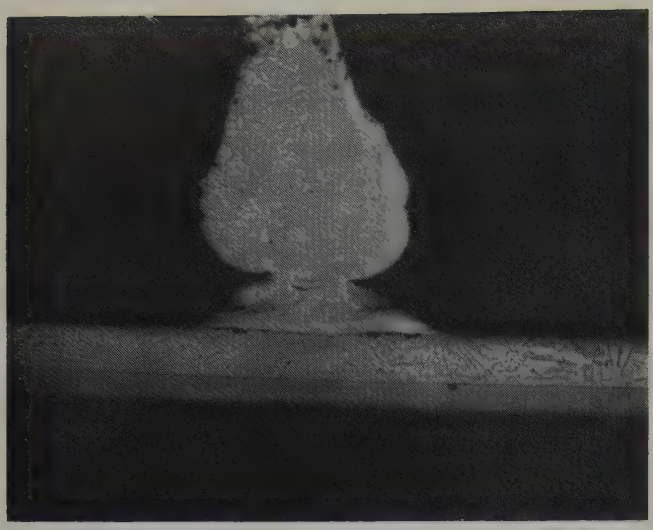


Fig. 15—"Hour-glass" attachment of Au-Sn plus 1% In to Al-Si surface. (From a 50 X photomicrograph)

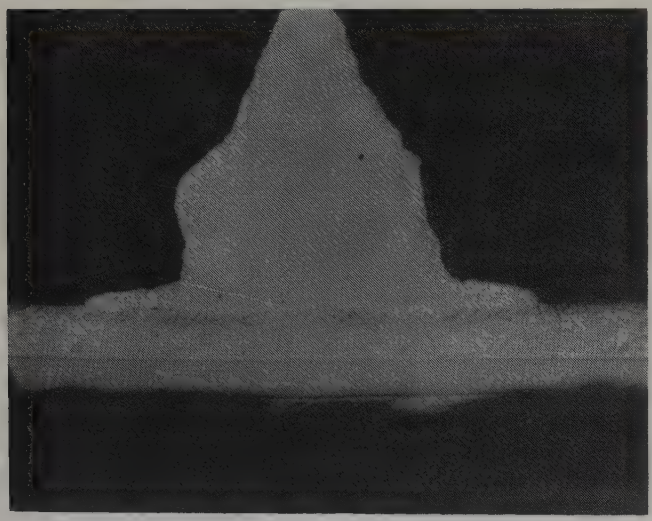


Fig. 16—"Full Wetting" attachment of Au-Sn plus 2% In to Al-Si surface. (From a 50 X photomicrograph)

Al-Si interface for this particular geometry, all other things being equal. The attachment was solely that of Au-Sn to the wire.

From the earlier investigation, it was found that additions of small percentages of indium (up to 2%) improved wetting properties. Preforms of Au-Sn-In were made and assembled with suitable wire material. After proper jigging, satisfactory attachments were made. From the hour-glass shape of the attachment, as seen in Fig. 15 (approximately 1% In), it is apparent that a difference still exists in wettability of the Au-Sn for the wire and for the Al-Si eutectic. The addition of indium was probably just sufficient to improve the wetting of the eutectic to the degree required to make a satisfactory bond.

Figure 16 shows the improvement of wetting to the Al-Si surface by the addition of 2% indium to the Au-Sn eutectic. It is expected that similar results might be anticipated for the Au-Ge and Au-Si systems.

In the aforegoing studies Wittry[24] confirmed the identity of phases formed in these attachments by means of the electron probe X-ray microanalyzer. As expected, the purple phases were shown to be $Au\text{-}Al_2$ and the goldish ones Au_2Al.

Summary

1. Molybdenum tabs should be used where possible because of its excellent expansion match and high electrical and thermal conductivities.
   The iron-nickel alloys may be used as tab material where thermal and electrical conductivity are unimportant but magnetic properties are necessary.
   Nickel is not recommended as a tab material because of its poor expansion match to silicon or germanium.
2. Crack-free bonds can be made to the following types of coatings on the aforementioned tabs:
   A. Gold or gold-alloy clad or plated.
   B. Tin* or antimony coated on top of the gold tabs.
   The tin and antimony parts are less sensitive to furnace ambient than the straight gold or gold alloy coatings, which require pure, dry, reducing atmospheres. Pure dry hydrogen is recommended as the best universal gas atmosphere.
3. Additions of 5 wt% indium to gold improve the wetting properties to silicon and germanium.
4. 80 Au-20 Sn readily wets and alloys to silicon and germanium under non-critical ambient conditions, but produces cracking.
5. Additions of up to 6% silicon to the gold-tin eutectic decrease its solubility for silicon and germanium without seriously impairing its wetting properties and reduces cracking.
6. Additions of up to 2% indium to the gold-tin eutectic improve its wettability of silicon and germanium and reduces cracking. Greater additions decrease its wettability.
7. A strong mechanical and metallurgical bond can be made directly to Al-Si surfaces without flux and/or agitation by means of the Au-Sn eutectic.
8. Indium additions to the gold-tin, up to 2 wt%, improve its wetting properties on Al-Si.
9. Two gold-aluminum compounds may be formed in electrode attachments: $AuAl_2$ and Au_2Al. $AuAl_2$ has been referred to as the "purple plague" because of its appearance. Its thermal expansion increases rapidly above 300°C. Its formation has been noted in the presence of silicon at temperatures as low as 425°C and in the presence of both silicon and tin at temperatures as low as 375°C.

*If tin coated tabs are used, precaution must be taken to see that less than stoichiometric tin is deposited. This allows an excess ductile gold layer remaining on the tab. Although this technique eliminated the cracking in silicon attachments, the problem still exists in germanium attachments. It is felt that the greater solubility of germanium in Au Sn is in some way connected with this problem; perhaps thinner Sn deposits will overcome this problem.

Acknowledgment

The author is indebted to William B. Warren (now deceased) and B. G. Bender of Hughes Semiconductor Products for criticism and discussion of some of the experimental results while conducting this work.

References

1 Taylor, T. C., *IRE, Trans. on Electron Devices,* 299-310 (July 1959).
2 Taylor, T. C., *IRE, Trans. on Electron Devices,* 358-359 (July 1959).
3 Taylor, T. C., *J. Appl. Phys.* 29, 865-866 (May 1958).
4 Sullivan, M. V. and Eigler, J. H., *J. Elect. Chem. Soc.* 103, 218-220 (April 1956).
5 Henkels, H. W., *Proc. IRE,* 46, No. 6, 1086-1098 (June 1958).
6 Peterson, J. W., McGlasson, Jr., J. and Hittinger, W. C., *Trans. AIME,* 209, 823-827 (July 1957).
7 Jenny, D. A., *Proc. IRE,* 41, 1728-1734 (December 1953).
8 Thomas, D. E. and Dacey, G. C., *IRE, Trans.* CT-3, 22-25 (March 1956).
9 Goldstein, B., *RCA Review,* Vol. XVIII No. 2, 213-220 (June 1957).
10 Mueller, C. W., *RCA Review,* Vol. XVIII No. 2, 205-212 (June 1957).
11 Pankove, J. I., *J. Appl. Phys.* 28, No. 9, 1054-1057 (Sept. 1957).
12 Rose, A. S., *RCA Review* VXII, No. 3, 423-432 (Sept. 1958).
13 Mueller, C. W. and Hilibrand, J., *IRE, Trans. on Electron Devices,* 2-5 (January 1958).
14 Gudmundsen, R. A., Waters, W. P., Wannlund, A. L., and Wright, W. V., *IRE, Trans. on Electron Devices,* ED-2, No. 1, 74-81 (January 1955).
15 Prince, M. B., *IRE, Trans. on Electron Devices,* ED-2, 8-9 (Oct. 1955).
16 Gudmundsen, R. A., and Maserjian, Jr., J., *J. Appl. Phys.* 28, No. 11 1303-1316 (November 1957).
17 Wannlund, A. L. and Waters, W. P., *IRE Wescon Convention Record,* Pt. 3, 3-5 (1957).
18 Bailey, G. L. J., and Watkins, H. C., *J. Inst. Metals* 80 (2) 57 (1951-1952).
19 Gudmundsen, R. A., et al, *Final Report on the SB1-1 Project,* SR-61, Hughes Aircraft Company (July 1 through October 2, 1957).
20 Zintl, Harder, and Hauch, Z. *Physik, Chem. B.* 35, 354-362 (1937).
21 Coffinberry and Hultgren, *Trans AIME,* 128, 249 (1938).
22 West and Peterson, Z. *Krist,* A. 88, 93 (1934).
23 Hansen, M., Constitution of Binary Alloys, McGraw-Hill Book Company, 69 (1958).
24 Wittry, D. B., Axelrod, J. M., and McCaldin, J. O., *Semiconductor Conference, AIME,* Boston (August 31–September 2, 1959).

APPLICATIONS ENGINEERING DIGESTS

APPLICATIONS ENGINEERING DIGEST NO. 68

Circle 198 on Reader Service Card

A 175 Mc Distributed Amplifier Using Silicon Mesa Transistors; Fairchild Semiconductor Corp., Mountain View, Cal. (P. J. Beneteau & L. Blaser)

Transistors can be used quite effectively as wideband distributed amplifiers. However, a serious problem presents itself with the later types of silicon mesa transistors in that the usual hybrid—pi equivalent circuit does not appear to be valid throughout a wide frequency range thus making difficult the proper design of the lines. A very simple scheme can be used, however, which yields good results with the 2N706, a transistor with an alpha-cutoff frequency in excess of 500 *mc*. The scheme consists of compensating the 6 *db* per octave drop in current gain by a 6 *db* per octave increase in base current. Four stages of the amplifier shown in Fig. 68.1 gave a voltage gain of about 20 *db* up to approximately 175 *mc*. The impedance level of both the input and output lines is 50 ohms.

Description of the Amplifier

The amplifier stage shown in *Fig. 68.1* contains four transistors arranged in conventional manner, with a base delay line and a collector delay line. These lines have identical characteristic impedances and delays. To maximize the gain, β_o (CE low frequency gain) and R_L should be maximized and R minimized. R_L is determined by circuit convenience (i.e. cabling size) and R is determined by the value of C and the proper corner frequency (see *Fig. 68.2*). The operating point is selected to maximize current gain. Where multiple stages are cascaded, the gain becomes

$$\left[\frac{n\beta_o}{2}\left(\frac{R_L}{R}\right)\right]^N$$

where N is the number of stages; n is number of transistors per stage.

As a pulse amplifier, it is capable of

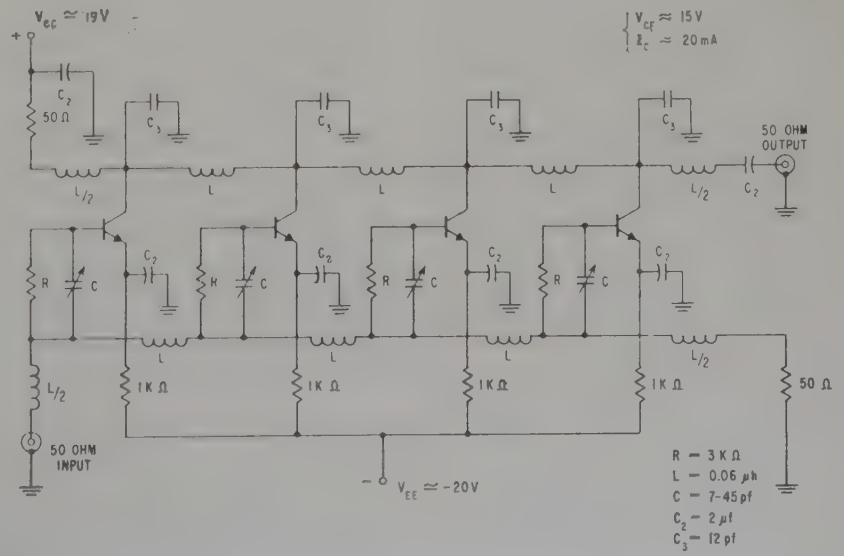


Fig. 68.1—Four-stage wideband distributed amplifier.

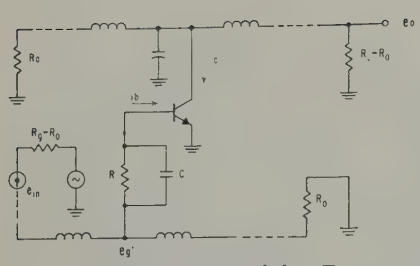


Fig. 68.2—Determining R.

a 3 $m\mu$ sec risetime. The dynamic range is an output of 4 volts *p.p.* with no distortion.

Design of the Amplifier

In contrast with other types of distributed amplifiers, this type is extremely simple to design. The design steps are as follows:

1.) Select Z_o and f_c, where f_c is say 1.5 times the upper frequency of interest.

2.) From the equations

$$Z_o = \sqrt{\frac{L}{C}}$$

$$f_c = \frac{1}{2\pi\sqrt{LC}},$$

$$L = \frac{Z_o}{\pi f_c} \text{ and } C = \frac{1}{\pi f_c Z_o}.$$

3.) Select R to give the proper corner frequency

$$\frac{1}{2\pi RC} = \frac{f_t}{\beta_o}$$

where

f_t = frequency at which $h_{fe} = 1$
β_o = low frequency current gain

In practice, C is usually a trimmer, and the adjustment is made with the help of a sweep generator. Since there is very little variation in the output capacitance of the transistors used, the collector capacitance does not need to be a trimmer, but C_{ob} and stray wiring capacitance ($\simeq$ 5 *pf*) should be taken into account.

APPLICATIONS ENGINEERING DIGEST NO. 69

Circle 199 on Reader Service Card

Transistor Power Derating and Thermal Resistance; The Bendix Corp., Bendix Semiconductor Div., Holmdel, N.J.

Fundamental to a discussion of the transistor power dissipation derating curve is a definition of thermal resistance. This parameter, stated simply, is the resistance offered by a material to the flow of heat from a point of higher thermal potential (e.g., transistor junction temperature) to a point of lower thermal potential (transistor mounting base or other external temperature reference point) and is expressed as the ratio of the thermal potential difference (degrees Centigrade) to the measure of thermal energy flow (watts), or:

$$\theta_R = \frac{°C}{W}$$

Thermal Derating Curve

The transistor power derating curve shown in *Fig. 69.1* describes the maximum allowable power dissipation for a typical alloy junction transistor with thermal resistance (junction to mounting base) of 2°C/*W* at any given mounting base temperature, considering the chassis on which the transistor is mounted as the reference point.

The general equation determining the maximum allowable power dissipation (P_c) in a given transistor is as follows:

$$P_c = \frac{T_j - T_R}{\theta_{R\ (J-R)}}$$ (This equation applies only to the sloped portion of the curve.)

where

T_j = Maximum junction temperature

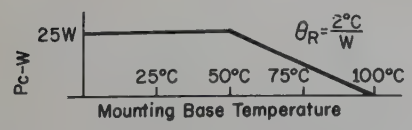


Fig. 69.1—Transistor derating curve.

T_R= Reference temperature
$\theta_{R\ (J-R)}$ = Thermal resistance (measured from junction to reference point.)

For example, a power transistor rated at maximum P_c of 25 watts and maximum junction temperature of 100°C, with a thermal resistance of 2°C/*W*, junction to mounting base, is to be operated in a condition where the reference point temperature is 60°C. What is the maximum allowable power dissipation?

Substituting in the equation, we have:

$$T_j = 100°C$$

$$T_R = 60°C$$

$$\theta_{R\ (J-R)} = 2°C/W, \text{ and}$$

$$P_c = \frac{100°C - 60°C}{2°C/W}$$

$$P_c = \frac{40°C}{2°C/W} = 20 \text{ watts}$$

From the equation it is also evident that, given a power dissipation and thermal resistance, the maximum allowable reference point temperature may be determined:

$$T_{max} - P_c\,[\theta_{R\ (J-R)}] = T_{ref}$$

The reference point generally used for power transistors is the heat sink mounting base on which the transistor package is placed. In calculating θ_R, one must be careful to include the additional resistance encountered due to resistance at the interface between the transistor case platform and the heat sink surface on which it is mounted.

The Thermal Equivalent Circuit

For the steady state condition, the thermal equivalent circuit for power transistors is one involving heat transfer by means of convection, conduction, and radiation from the transistor junction to the environment and may be drawn as shown in *Fig. 69.2*. The symbols are defined below.

P is power dissipated at the junction
T_j is junction temperature in °C
θ_{J-C} is thermal resistance junction-case
T_c is case temperature in °C
θ_{C-S} is thermal resistance case-heat sink or mounting base
T_s is mounting base or heat sink temperature in °C
θ_{S-A} is mounting base resistance (heat sink-free air)
TA is the ambient temperature of the free air surrounding the heat sink.

From the foregoing circuit we can write the following thermal equation:

$$P = \frac{T_j - TA}{R_T}$$

where $R_T = R_{J-C} + R_{C-S} + R_{S-A}$, P is in watts, T is in degrees centigrade, and R_T is in degrees C/*W* (commonly θ_R). The reference point temperature in this case is taken as that of the ambient air on the assumption that its temperature will be affected negligibly by the power dissipated by the transistor. In cases where the heat sink temperature is also affected negligibly by the power dissipated by the transistor it may be taken as the reference point and R_{S-A} is then omitted from the calculation.

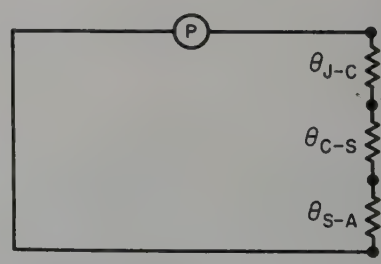


Fig. 69.2—Thermal equivalent circuit.

APPLICATIONS ENGINEERING DIGEST NO. 70

Circle 200 on Reader Service Card

Zener Protection Circuits for Aircraft Voltage Surges; Motorola Semiconductor Products Inc., Phoenix, Ariz. (R. Greenburg and J. Takesuye)

Many designs of airborne electronic equipment embody transistors required to work almost directly from the 28-volt bus. The 28-volt source may reach a maximum of 80 volts during transient periods. If inductive or transformer-coupled circuits are used, the transistors could have a transient of 160 volts imposed across them. Needless to say, commercially available transistors do not meet the 160-volt requirements. A 30-volt zener diode placed across each transistor will suppress the excess voltage. Or a 30-volt zener can be placed across the input of the equipment. The 30 volts is arbitrary, but will allow low-voltage components to be used. If power dissipation is excessive, an interruptive type circuit breaker in conjunction with a zener may be necessary.

The 400-cycle 115-volt line in the aircraft may carry as much as 190 volts during transient periods. The a-c operated equipment can be protected with two zeners back to back forming an a-c clipper. The same considerations which apply to the 28-volt protection zeners above also apply to the zeners used as clippers.

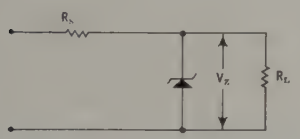


Fig. 70.1—Basic shunt protection.

Fig. 70.2—Temperature change vs. input voltage.

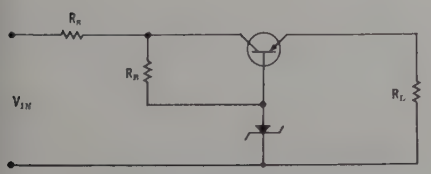


Fig. 70.3—Emitter follower regulator.

Basic Shunt Protection

The basic protection circuit using a shunt zener is shown in *Fig. 70.1*. The circuit applies whether an individual component or complete equipment is to be protected.

The maximum zener current occurs when the load current is zero.

$$I_{Z\,max} = \frac{V_{IN} - V_Z}{R_S}. \qquad (1)$$

Maximum steady state power dissipated in the zener diode, P_{Zmax}, equals $I_{Z(max)} \times V_Z$. Thus,

$$P_{Z\,max} = \frac{V_{IN} - V_Z}{R_S} V_Z \qquad (2)$$

With the Motorola 10-watt and 50-watt zeners, the thermal time constant is about 50 milliseconds. The following expression relates the rise in junction temperature as a function of other variables.

$$\Delta T = T_J - T_{MB} = \theta_{JC} P_{Z\,max} (1 - e^{-t/RC}) \qquad (3)$$

where RC is the thermal time constant. Substituting $P_{Z(max)}$ into Equation 3,

$$\Delta T = \frac{\theta_{JC}}{R_S} [(V_{IN} - V_Z)\, V_Z] (1 - e^{-t/RC}). \qquad (4)$$

Using the following constants:

$\theta_{JC} = 2.4$°C/watt,
$RC = 50$ milliseconds, and
$V_Z = 30$ volts,

Equation 4 becomes

$$\Delta T \quad \frac{72\, V_{IN} - 2160}{R_S} (1 - e^{-t/0.05}). \qquad (5)$$

A plot of ΔT as a function of V_{IN} and t is shown in *Fig. 70.2* for several zener voltages. These plots are for 50-watt devices. Using the 30-volt, 50-watt zener diode the maximum rise in junction temperature occurs at 72.5 volts as can be seen from *Fig. 70.2*.

$$\Delta T_{max} = \frac{2650}{R_S}. \qquad (6)$$

The Motorola zener diodes have a maximum junction temperature of 175°C. The series resistance, R_S, which includes the 28-volt source resistance, and the mounting base temperature determine the number of zener diodes necessary to avoid the 175°C maximum junction temperature. The general expression relating Q, the number of zener diodes needed, is as follows:

$$Q = \frac{\Delta T_{max}}{175 - T_{MB}}$$

$$\theta_{JC} \frac{(V_{IN} - V_Z)\, V_Z (1 - e^{-t/RC})}{R_S (175 - T_{MB})} \qquad (7)$$

ΔT_{max} must be determined by plotting ΔT as a function of V_{IN} and t for a particular zener voltage using Equation 4.

Using *Fig. 70.2* for a 50-watt, 30-volt zener diode the number of zeners needed is

$$Q = \frac{2650}{R_S (175 - T_{MB})}. \qquad (8)$$

In some cases when R_S is small, the number of zeners required will be large. This makes impractical the protective scheme used previously; therefore some other type of circuit must be used to eliminate the high zener dissipation. A circuit that will reduce this high-power dissipation in zeners is the "emitter-follower" regulator, shown in *Fig. 70.3*.

Interruptive Protection Circuit

When it becomes impractical to keep adding zeners to accommodate the thermal load, a self-interruptive type of circuit will decrease the zener power dissipation (see *Fig. 70.4*.)

The circuit breaker must open in less than 10 milli-seconds to do any good. For example:

Assume the breaker is closed for 10 milliseconds and open for 15 millisec-

(Continued on page 69)

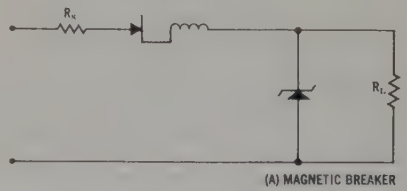


Fig. 70.4—Interruptive protective circuit.

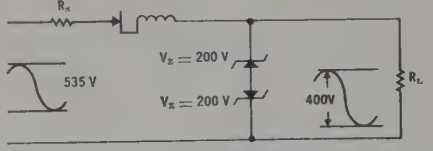


Fig. 70.5—A-C protection circuit.

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from June 2, 1959 to June 30, 1959. In subsequent issues, patents issued from June 30, 1959 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.

June 2, 1959

2,888,736 Transistor Packages—J. J. Sardella. Assignee: Raytheon Mfg. Co. A means for encapsulating a junction transistor in an air tight metal casing.

2,889,206 Recovery of Selenium—N. A. Hobin. Assignee: Kawecki Chemical Co. A method of recovering selenium from rectifier scrap material.

2,889,240 Method and Apparatus for Growing Semiconductive Single Crystals From a Melt—F. O. Rosi. Assignee: RCA. A temperature gradient of between 150°C/cm and 400°C/cm is maintained in a solid crystal frozen out from and adjacent to a melt, said gradient resulting in higher charge carrier lifetime in said crystal.

2,889,416 Temperautre Compensated—Transistor Amplifier—R. F. Shea. Assignee: General Electric Co. A transistor amplifier possessing a degenerative feedback path with a temperature sensitive resistance, variations of which changes the amount of degeneration to result in temperature compensated operation.

2,889,417 Tetrode Transistor Bias Circuit—J. T. Maupin, R. J. Zelinka. Assignee: Minneapolis-Honeywell Regulator Co. A transverse voltage gradient between the base electrodes of a tetrode transistor causes improvement in the linearity of the dynamic response of the device.

2,889,453 Tunable Transistor Radio Frequency Amplifier Having Approximately Constant Bandwidth—A. P. Stern. Assignee: General Electric Co. A series resonant frequency transfer network compensates for changes in transistor input impedance with frequency.

2,889,460 Electrical Apparatus—R. J. Ehret. Assignee: Minneapolis-Honeywell Regulator Co. A transistor oscillator circuit employing a single a-c bias source.

2,889,467 Semiconductor Integrator—R. O. Endres, D. E. Devitch. Assignee: RCA. An integrator circuit for integrating unipolar pulse information and with certain modifications bipolar signals.

2,889,468 Binary Coded Decade Counter—R. L. Crosby. Assignee: Sperry Rand Corp. A nonsymmetrical single transistor flip-flop circuit which can be triggered with positive and negative pulses.

2,889,469 Semiconductor Electrical Pulse Counting Means—M. W. Green. Assignee: RCA. Frequency dividing and impulse counting circuits using a single multielectrode semiconductor device.

2,889,498 Semiconductor Rectifier Assembly—J. L. Boyer, H. S. McWilliams, A. P. Colaiaco. Assignee: Westinghouse Electric Corp. A semiconductor power rectifier system in which the cooling system is separate from the rectifier device so that the latter can be replaced without disturbing the former.

2,889,499 Bistable Semiconductor Device—R. F. Rutz. Assignee: IBM. A p-n junction and a point contact region within the same structure provide a device in which a small control current can drive the collector current from low values to very high values.

2,889,500 Selenium Rectifier—P. E. Lighty. Assignee: International Telephone and Telegraph Corp. Mercuric selenide added to halogen containing selenium is incorporated into a device to provide a high rectification ratio.

2,889,510 Two Terminal Monostable Transistor Switch—R. L. Carmichael. Assignee: BTL. A regeneration circuit eliminates destructive readout of information from a memory circuit.

2,889,512 Direct Current Transistor Voltage or Current Regulators—G. M. Ford, B. D. Tague. Assignee: USA (Dept. of the Navy). Series type transistor regulator.

2,889,519 Clamp Type Current Transducer—G. F. Montgomery, G. Stansburg. Assignee: USA (Dept. of Commerce). A portable, battery powered, clamp type, transistorized microammeter.

2,889,537 Electronic Selector Switch—G. Elliot. Assignee: General Dynamics Corp. A semiconductor selector switching circuit.

June 9, 1959

2,890,139 Semiconductive Material Purification and Method—W. Shockley. Assignee: None. A method which includes forming and controlling the size of a puddle of molten semiconductor material contained within a portion of solid material.

2,890,142 Asymmetrically Conductive Device—F. A. Kroger, D. de Nobel. Assignee: North American Philips Co. A cadmium telluride device.

2,890,159 Method of Etching A Surface of Semiconductor Device—A. Amaya. Assignee: Sony Kabushikikaisha (Japan). The surface of an n-p-n germanium alloy junction transistor is etched in a solution of 25% phosphoric acid during which period the emitter and collector of the device are alternately subjected to currents of 500 ma to 800 ma.

2,890,293 Transistor Amplifier Having Simultaneous Gain and Selectivity Control—A. J. Van Overbeck. Assignee: North American Philips Co. An amplifier operated with a transistor in a grounded base configuration.

2,890,350 Image Converter—A. Lempicki. Assignee: Sylvania Electric Products Inc. An image converter employing infrared photoconductive quenching.

2,890,352 Amplitude Discriminatory System—H. C. Goodrich. Assignee: RCA. A semiconductor signal clipping circuit which is not susceptible to changes in applied signal level.

2,890,353 Transistor Switching Circuit—J. T. Van Lottum, A. J. Van Overbeck. Assignee: North American Philips Co. A switching circuit which exhibits a current-voltage characteristic similar to that of a gas discharge tube.

2,890,386 Automatic Headlamp Control System—E. G. Matkins, K. A. Skinner. Assignee: General Motors Corp. A high-beam low-beam switching circuit.

2,890,395 Semiconductor Construction—J. W. Lathrop, J. R. Hall. Assignee: USA (Dept. of the Army). A p-n-p diffused base germanium transistor integrally incorporated in a printed circuit plate.

2,890,403 Transistor Pulse Generator—H. H. Van Abbe. Assignee: North American Philips Co. Pulses are produced by feedback of voltage produced across a transformer winding to the base electrode of a transistor.

2,890,404 Generator Control System Employing Semiconductor Apparatus. D. L. Cronin. Assignee: Minneapolis-Honeywell Regulator Co. In a generator control system each field winding is associated with an individual control transistor.

2,890,418 Nonlinear Semiconductor Signal Translating Circuits—J. Zawels. Assignee: RCA. A balanced signal demodulator circuit.

*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

June 16, 1959

2,890,976 Monocrystalline Tubular Semiconductor—K. Lehovec. Assignee: Sprague Electric Co. A process for the manufacture of a tubular semiconductor suitable for use as a bomb-type reaction chamber or in electrical applications.

2,891,145 Detector and AGC System—W. Bradmiller. Assignee: Avco Mfg. Corp. A power detector, including an emitter follower as a diode load, having a load impedance separate from varying audio and AGC loads.

2,891,146 Manual Volume Control For Transistor Audio Stage Utilizing Both Variable Attenuation and Variable Degeneration—J. L. Sciurba. Assignee: Motorola Inc. Circuit for radio receiver.

2,891,156 Detector Circuit—R. P. Crow. Assignee: Motorola Inc. An F-M discriminator circuit having a narrow response band.

2,891,159 Phase Shift Oscillator—E. Y. Politi, M. T. Williams. Assignee: Lockheed Aircraft Corp. A transistorized phase shift oscillator with frequency stability independent of temperature induced transistor parameter changes.

2,891,160 Semiconductor Oscillators—A. Leblond. Assignee: Compagnie Generale de Telegraphic Sans Lib (France). A VHF/UHF, transistor oscillator circuit.

2,891,169 Electroluminescent Device To Give Negative Pictures—F. H. Nicoll. Assignee: RCA. A radiant energy translating device for producing images in reverse, i. e. negative form.

2,891,170 Sequential Pulse Generator—S. Paull. Assignee: None. A magnetic core sequential pulse generator which draws energy from the power source only during core flux reversals.

2,891,171 Transistor Switch—W. Shockley. Assignee: Consolidated Electrodynamics Corp. In a current-control circuit, means for preventing introduction of spurious signals.

2,891,172 Switching Circuits Employing Junction Transistors—R. Henle, G. D. Bruce. Assignee: IBM. Inverter or logic circuits.

2,891,173 Sawtooth Wave Generator—W. A. Helbig. Assignee: RCA. A constant amplitude transistorized sawtooth wave generator.

2,891,174 Electronic Integrator—R. R. Hawkins. Assignee: Minneapolis-Honeywell Regulator Co. An a-c integrator circuit having linear operation over a wide range of voltage signal inputs.

2,891,192 Sawtooth Wave Generator—H. C. Goodrich. Assignee: RCA. A single transistor self-oscillating sawtooth wave generator.

2,891,195 Lamp Flasher with Daylight—Responsive Inhibiting Means—H. L. Smyth. Assignee: National Research Council (Canada). Transistorized cyclic flasher control circuit with means for terminating flashing at the onset of daylight.

2,891,197 Photoelectric Transistor Switch Control—J. H. Guyton, Assignee: General Motors Corp. Automobile headlight control circuit for activating headlights in response to the ambient light level.

2,891,201 Crystal Contact Device—W. H. Cooper. Assignee: International Telephone and Telegraph Corp. Means for reducing the thermal conductivity of crystal supporting means in a crystal diode assembly.

2,891,202 Semiconductor Device—E. L. Geissinger, J. H. Wyman. Assignee: Bendix Aviation Corp. Method of producing an evacuated envelope enclosing a semiconductor device.

2,891,203 Silicon Rectifiers—G. G. Thornton. Assignee: Sylvania Electric Products Inc. A process for manufacturing silicon rectifiers which includes bombarding the surface of a silicon body with oxygen ions in a reduced pressure atmosphere at about 250° C for approximately one hour.

2,891,219 Low Current Resistance Measuring Device—R. W. Camp. Asignee: None. A device for measuring the resistance of explosive powder mixes or compositions.

June 23, 1959

2,891,726 Multiplier Circuit—R. O. Decker, K. Chen.—Assignee: Westinghouse Electric Corp. A temperature-stable, four-quadrant, analog multiplying circuit.

2,892,045 Class B Transistor Amplifier—A. I. Aronson. Assignee: RCA. A capacitively coupled class B amplifier with linear input impedance to eliminate signal induced bias voltage variations on the transistor.

2,892,099 Semiconductor Adder—R. L. Gray. Assignee: Burroughs Corp. A Coincidence type semiconductor binary adding circuit.

2,892,100 Power Transistor Switching Circuits—E. Solbodzinski, C. Huang. Assignee: Sylvania Electric Products Inc. A bistable switching circuit for high current switching applications wherein currents are in the order of amperes.

2,892,101 Transistor Time Delay Circuit—R. L. Bright. Assignee: Westinghouse Electric Corp. A series resistance-capacitance circuit actuates transistor switches in a manner to provide rapid and sensitive control of the overall circuit output.

2,892,102 Frequency Halver—J. F. Reuther, S. D. Silliman. Assignee: Westinghouse Electric Corp. A frequency halver utilizing a single source of bias voltage.

2,892,103 Gating Circuits For Electronic Computers—A. Dale. Assignee: Thompson Ramo Wooldridge Inc. Means for coupling bistable circuits to a gating network which is controlled by said circuits.

2,892,135 Small Enclosed Electrical Device—W. C. Woods. Assignee: Sylvania Electric Products Inc. A cylindrical envelope, and its method of manufacture, for encasing a semiconductor diode.

2,892,136 Rectifier With Multiple Barriers—C. A. Escoffery. Assignee: International Rectifier Corp. In a selenium rectifier assembly, multiple barrier layers are placed between the selenium layer and the counter electrode, said layers including a cadmium salt layer, and an organic film-forming material.

2,892,143 Generator Regulating Apparatus—R. D. Sommer. Assignee: Essex Wire Corp. In a low voltage generator system, a transistor circuit is used to regulate the generator, said circuit being energized by the output of the generator.

2,892,156 Crystal Diodes—J. W. Dawson. Assignee: Sylvania Electric Products Inc. Apparatus for automatic sequential testing of point contact crystal diodes.

2,892,164 Semiconductor Filter Circuits—H. J. Woll. Assignee: RCA. An arrangement for removing ripple from a d-c power supply circuit.

2,892,165 Temperature Stabilized Two Terminal Semiconductor Filter Circuit—J. E. Lindsay. Assignee: RCA. A circuit for use with d-c power supplies.

June 30, 1959

2,892,700 Method For Separating and Purifying Germanium from Substances Containing Metallic Germanium—O. Rosner. Assignee: None. A process which includes heating the metallic germanium-containing substance to a high temperature in a CO_2 atmosphere to convert the metallic germanium to germanium monoxide.

2,892,739 Crystal Growing Procedure—G. W. Rusler. Assignee: Minneapolis-Honeywell Regulator Co. A crystal pulling technique with means for controlling the impurities within, and the volume of the melt.

2,892,763 Production of Pure Elemental Silicon—Q. H. McKenna, D. F. Stern. Assignee: American Potash & Chemical Corp. Silicon is produced at the cathode of electrolytic cell wherein silicon carbide comprises the anode and the electrolyte is an alkali-chloride/alkali-fluosilicote mixture.

2,892,931 Transistor Radio Apparatus—R. C. Koch. Assignee: I.D.E.A. Inc. Circuitry for a transistorized radio receiver.

2,892,932 Automatic Gain Control For Transistor Receiver Circuits—R. L. Layburn, B. R. Stachiewicz. Assignee. General Dynamics Corp. A forward acting gain control circuit which does not require a d-c amplification stage.

2,892,952 Ramp Function Transistor Circuit—E. S. McVey. Assignee: USA (Dept. of the Navy). A circuit for producing linear ramp voltages directly proportional to the time interval of the gating pulses applied to said circuit.

2,892,953 Coincidence Gate Transistor Circuit—E. S. McVay. Assignee: USA (Dept. of the Navy). A circuit which produces an output pulse only when the dual input pulses are in coincidence, said output having a magnitude equal to that of the smaller input signal.

2,892,966 Automatic Lamp Changes—H. L. Smyth. Assignee: National Research Council (Canada). A system for monitoring a lamp flasher such as those found in navigational bouys, and for automatically changing lamps when a light failure has been indicated.

2,892,979 Diode Amplifier—W. A. Ogletree. Assignee: Burroughs Corp. The temporary dynamic impedance characteristic of a germanium junction diode is employed to produce amplification of small low power current signals.

(To be Continued)

SEMICONDUCTOR & SOLID-STATE BIBLIOGRAPHY

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Infra-Red Scanners for Airborne Reconnaissance	Br Comm & Elecncs Feb 1961	This article surveys the advantages which infrared systems offer, together with some of the practical problems of system design.	C. M. Cade
Etching and Polishing Studies on Magnesium Oxide Single Crystals	Brit JL Appd Phys Feb 1961	The action of two etchants on magnesium oxide has been studied. Etch pits, pyramids, and hillocks may be produced, and both etchants dissolve away the crystal surface.	K. T. Ghosh F. J. P. Clarke
Design Curves Aid Proper Utilization of Thermoelectric Devices	Can Elecncs Engg Feb 1961	Diagrams are given from which the performance data of Frigistors under various conditions can be obtained. Their use is illustrated by two examples: a refrigerated box and a vacuum pump baffle.	A. Gelbtuch C. A. A. Macphee
Semiconductor Materials Provide Key to Thermoelectric Developments	Can Elecncs Engg Feb 1961	Research is opening up new market prospects for such devices. Surveys show that supply of raw materials can keep up with demand.	R. P. Poslawski
Thermoelectric Cooling Improves Baffles For Vacuum Pumps and System	Can Elecncs Engg Feb 1961	A thermoelectric baffle has been developed for use as a refrigeration element in vacuum pumping systems, which can operate down to temperatures that are adequate for the condensation of commonly used diffusion pump fluids.	R. P. Poslawski
The Development of Thermoelectric Materials for Refrigeration	Can Elecncs Engg Feb 1961	Five months after the Needco laboratory buildings were completed, materials suitable for thermoelectric cooling application were produced which equalled the currently accepted standards of the industry.	C. A. A. Macphee
Low Impedance Thermoelectric Devices Power Tunnel Diodes	Can Elecncs Engg Feb 1961	Tunnel diodes, being very low impedance devices, require low impedance power sources. Conventional supplies are bulky and inefficient. Introduction of new thermoelectric devices made it feasible to build supplies with desirable characteristics.	E. L. R. Webb J. K. Pulfer
Transistorized Circuitry For Road Machinery Control	Control Engg Feb 1961	All-transistor control with a computing circuit solves problem of compensating for time delays introduced by mechanical actions.	J. T. Bowen R. M. Walp
Transistorized AGC Circuit is Gated for Better Operation	Elecl Des News Feb 1961	A keyed AGC system samples collector signal of a video output stage in a transistorized TV. This system has good noise clipping and minimizes contrast changes with large input signal variation.	Motorola, Inc.
Alloy-Diffused Transistors	Elecnc Engg (Br) Feb 1961	Shows why the conventional method of manufacturing alloy junction transistors is incapable of further exploitation at V.H.F. The method of making the alloy-diffused transistor is given together with the reasons for its advantage.	E. Wolfendale
High Speed DC Comparator	Elecnc Equip Eng. Feb 1961	In telemetry systems, test equipment or analog to digital converters, a sensitive comparator is necessary. This transistor comparator is designed for a sensitivity of better than five millivolts, yet is capable of high-speed operations and performance beyond 100°C.	C. D. Todd M. M. Morishita
Portable Transient Voltage Indicator	Elecnc Equip Eng. Feb 1961	Overvoltages beyond the predetermined level trigger indicators for use in semiconductor tests. This device is accurate within two per cent of full range for transients as short as one microsecond.	F. W. Gutzwiller
Trinistor Controlled-Rectifier Pulse Control	Elecnc Equip Eng. Feb 1961	The new npnp negative resistance device, the trinistor controlled rectifier, can be operated as a highly efficient d-c switch. However, it can be turned off only by reducing its current for a short time. Several circuits that efficiently perform this function are outlined.	J. Geisler
Transistorized FM Wireless Mike	Elecnc Ind Feb 1961	Complete details for constructing the compact unit are given along with design information for making changes to suit the user's application.	S. J. Lanzalotti
The Tunnel Diode as a Pulse Generator	Elecnc Ind Feb 1961	After graphically analyzing the tunnel diode's action as a square wave generator, the author synthesizes a pulse generator which exploits the device's ability to switch more rapidly through the peak, rather than the valley, current region.	P. Mauch
Understanding Silicon Photocells	Elecnc Ind Feb 1961	Photocell characteristics are analyzed and explained.	W. Luft
Using Thermistors as Servo Elements	Electronics Feb 3, 1961	Indirectly heated thermistors can be substituted for mechanical servo units in some applications. Basic circuit is a thermistor potentiometer.	I. C. Hutcheon
Designing Tunnel Diode Oscillators	Electronics Feb 10, 1961	Tunnel diode relaxation oscillators are analyzed, and the circuits for frequency-stabilized sinusoidal and square-wave generators are derived.	Wen-Hsiung Ko
Designing Tunnel - Diode R-F Amplifiers	Electronics Feb 17, 1961	Stripline techniques coupled with a tunnel-diode amplifier make a miniaturized r-f amplifier having a stable insertion gain of 25 db and a theoretical noise figure of 2.7.	E. D. Long C. P. Womack
Root - Mean - Square Sensing in Voltage Regulators	Electronics Feb 17, 1961	Direct voltage proportional to rms value of chopped sine or square waves is obtained from self-biased linear rectifier circuit intermediate in action between average and peak rectifiers.	R. L. Frank
Transistor Amplifier Slide Rule Calculator	Electronics Feb 17, 1961	This slide rule (includes layout) provides a fast, accurate method for calculating transistor amplifier values.	J. Hallis
Semiconductor Strain Gages Offer High Sensitivity	Electronics Feb 24, 1961	Single crystal silicon structures provide sensitivity nearly two orders of magnitude greater than their metal counterparts. Devices are adaptable to small area strain measurements.	E. E. Talmo
Phantastron Circuits Using Transistors	Electronics Feb 24, 1961	Three transistors are required to produce characteristics equivalent to those of pentode vacuum-tube phantastron circuits. The pentode circuit uses feedback to give regeneration and amplification within one envelope.	N. C. Hekimian

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Transistor Measurements	Elecn Tech Feb 1961	Equipment for the direct measurement, at frequencies from 0.5 to 100 Mc/s., of the power gain and noise factor of transistors operating as small-signal common-emitter amplifiers is described. The results of a few typical measurements made under defined conditions of external feedback are included.	B. N. Harden R. W. Smith
Semiconductor Electronics: 5 Transistor Amplifier Designs	Electro-Technology Feb 1961	Instructions are given for drawing load lines and determining operating point. Small signal parameters and their variation with changes in operating point are discussed. Absolute maximum ratings are defined.	A. A. Sorensen
Properties of Thin Antimony Films Deposited in High Vacuum	JL Appl Phys Feb 1961	The principal cause of the formation of heterogeneous films of antimony appears to be impurities in the residual atmosphere during deposition. (Letter to Editor.)	G. A. Condas B. R. Banerjee
Current Voltage Characteristics of Alloyed and Diffused p-n Junction Diodes in InSb	JL Appl Phys Feb 1961	A presentation is made of the current voltage characteristic of InSb material at liquid nitrogen temperature and a short analysis of the characteristic is given. (Letter to Editor.)	H. J. Stocker
Analytical Solutions for some Zone Melting Problems	JL Appl Phys Feb 1961	Analytical solutions to the zone melting problem are generated for the infinite straight bar and for the re-entrant annular ring geometries.	H. Reiss E. Helfand
Thermo-Electric Behavior of p-n Junctions	JL Appl Phys Feb 1961	Equations are derived for carrier and heat flow resulting from the existence of a temperature and a potential gradient across a p-n junction. P-N junction thermoelectric conversion efficiency is compared with the efficiency of homogeneous semiconductors and thermionic diodes.	M. Cutler
Antimony-Rich Surface Layer on Diffused Germanium	JL Electrochem Soc Feb 1961	Report on the initial results of a study of the properties of an antimony-rich surface layer which has been observed to form during the diffusion of antimony into germanium from a vapor phase.	J. E. McNamara
Preparation of Uniform Resistivity n-Type Silicon by Nuclear Transmutation	JL Electrochem Soc Feb 1961	By the capture of a thermal neutron, the natural isotope Si^{30} can be transmuted into the unstable isotope Si^{31} which decays by beta emission with a 2.62 hr half-life to the stable isotope P^{1}. By means of this reaction, donors can be produced in a silicon crystal.	M. Tanenbaum A. D. Mills
N- and P-Type Single Crystal Bismuth Telluride	JL Electrochem Soc Feb 1961	Both p- and n-type single crystal Bi_2Te_3 have been grown by the Czochralski method. Some of these crystals were "dendritic like," similar to Ge dendrites reported by Billig.	A. C. Yang F. D. Shepherd
Radio-Frequency Carrier and Capacitive Coupling Procedures for Resistivity and Lifetime Measurements on Silicon	JL Electrochem Soc Feb 1961	By use of a radio-frequency carrier and capacitive coupling it has been possible to measure the resistance and lifetime of silicon rods without making direct ohmic contact to the samples.	I. R. Weingarten M. Rothberg
Study of Copper Precipitation Behavior in Single Silicon Crystals	JL Electrochem Soc Feb 1961	The precipitation behavior of copper in silicon crystals containing different amounts of oxygen has been investigated within the temperature range of 900°—1300°C.	G. H. Schwuttke
Infrared Enhancement and Quenching of Photoconduction in Single Crystals of ZnS:Cu	JL Electrochem Soc Feb 1961	An ohmic infrared photoconductivity peaking at 0.65 and 1.35 has been observed at room temperature in synthetic single crystals of ZnS: Cu. The photocurrents are constant with time, not dependent on any previous excitation, and linear with intensity.	F. G. Ullman J. J. Dropkin
Macroscopic Physics of Surface Recombination in Semiconductors	Jl Elecncs & Cont Feb 1961	It is shown that the concept of surface recombination velocity, commonly used to describe surface properties of transistor materials, is only valid when its magnitude is small compared with the diffusion velocity.	A. C. Sim
Composition Stability Limits of Binary Semiconductor Compounds	JL Phys & Chem Sol Feb 1961	The composition stability-limits of an essentially-ordered, non-degenerate, semiconductor crystal, MN, showing deviations from stoichiometry, are investigated under predetermined conditions.	R. F. Brebrick
Electron-Hole Scattering and Minority Carrier Mobility in Germanium	JL Phys & Chem Sol Feb 1961	In light of a theory of the effects of carrier-carrier scattering on mobility in semiconductors previously presented, the specific applications of the theory to germanium is discussed in the temperature and impurity concentration ranges where measurements of the minority carrier mobility have recently been performed.	T. P. McLean E. G. S. Paige
Diffusion of Silver, Cobalt, and Iron in Germanium	JL Phys & Chem Sol Feb 1961	It is found that: (1) in most cases, the concentration varies as $\exp(-X/L)$ rather than the Gaussian or the error function variation as usually expected from Fick's (second) Law. The diffusivities of these elements in Ge are in the range of 10^{-6} to 10^{-7} cm ^{2}/sec at temperatures around 800°C.	L. Y. Wei
X-Ray Determination of Crystal Structures	Philips Tech Rev Feb 16, 1961	This article discusses the principles underlying x-ray diffraction, the relation between the structure and the structure patterns, and how one can be derived from the other.	P. B. Braun A. J. van Bommel
Impurity Conduction in Silicon	Physical Review Feb 1, 1961	Emphasis in the investigation was placed on the study of samples of low impurity concentration where the conduction is attributed to charge exchange between impurity centers which are partially ionized by some compensating impurity.	R. K. Ray H. Y. Fan
Decay of Excess Carriers in Semiconductors. II	Physical Review Feb 1, 1961	A physical interpretation is given of the nonlinear differential equations which govern the decay of excess carrier populations through recombination centers.	K. C. Nomura J. S. Blakemore
Electron Effective Masses of InAs and GaAs as a Function of Temperature and Doping	Physical Review Feb 1, 1961	Measurements have been made at room and liquid nitrogen temperatures. Masses have been determined from Faraday rotation and infrared reflectivity measurements.	M. Cardona
Physical Properties of Several II-V Semiconductors	Physical Review Feb 1, 1961	Energy gaps in these materials vary from approximately 0.13 to 1.0 ev. Mobilities at 297°K range from 10 to 15,000 cm^2/volt sec, and increase at low temperatures. Resistivity and mobility anisotropy have been investigated in detail for $CdAs_2$.	W. J. Turner A. S. Fischler W. E. Reese

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Excess Tunnel Current in Esaki Junctions	Physical Review Feb 1, 1961	Between high and low biases the current is unexpectedly high and has been called the excess current. A comprehensive experimental study has been made of this excess current in silicon junctions.	A. G. Chynoweth W. L. Feldman R. A. Logan
Defects in Irradiated Silicon I. Electron Spin Resonance of the Si-A Centers	Physical Review Feb 15, 1961	It is concluded that the Si-A center is a lattice vacancy with an oxygen atom impurity bridging two of the four broken bonds associated with the vacancy. Spin resonance and electrical activity arise from an electron trapped in the other two bonds.	G. D. Watkins J. W. Corbett
Surface Structures and Properties of Diamond-Structure Semiconductors	Physical Review Feb 15, 1961	Low energy electron diffraction and secondary electron-emission measurements have been made on (111) and (11T) surfaces of GaSb and (100) surfaces of InSb. A general model for (111) surfaces of diamond structure semiconductors is proposed.	D. Haneman
Tunneling Current in Esaki Diodes	Physical Review Feb 15, 1961	The integral giving the net tunneling current flow across the junction in an Esaki diode is evaluated. The resulting expression is plotted as a function of the applied voltages for various temperatures and donor concentrations. The resulting curves compare favorably with those of Esaki.	C. W. Bates, Jr.
Defects In Irradiated Silicon II. Infrared Absorption of the Si-A Center	Physical Review Feb 15, 1961	In this paper infrared measurements are presented which in conjunction with the spin resonance measurements of the preceding paper, establish the identity of the Si-A center.	J. W. Corbett G. D. Watkins R. M. Chrenko R. S. McDonald
Electrical Properties of n-Type GaSb	Physical Review Feb 15, 1961	The electrical conductivity and Hall coefficient of n-type GaSb doped with Se or Te have been measured at 77° and 300°K for samples with net donor concentrations between about $6x10^{16}$ cm^{-3} and $2x10^{18}$ cm^{-3}.	A. J. Strauss
10.8 KMC Germanium Tunnel Diode	Proc IRE Feb 1961	Investigations on germanium low time-constant junctions and low inductance-mount configurations have led to the construction of tunnel diodes oscillating at fundamental frequences up to 10.8 kmc.	G. Dermit H. Lockwood W. Hauer
Three-Terminal Variable Capacitance Semiconductor Device	Proc IRE Feb 1961	An n-p-n transistor with both junctions biased in the reverse direction forms the basis of a 3-terminal variable capacitance device. The effect is analyzed quantitatively.	J. L. Giacoletto
A Varactor Diode Parametric Standing Wave Amplifier	Proc IRE Feb 1961	Concepts are presented on the various types of varactor diode parametric standing-wave amplifiers originally conceived by Brett and under investigation at this laboratory for the past 18 months.	H. Brett F. A. Brand W. G. Matthei
Circuit Considerations Relating to Microelectronics	Proc IRE Feb 1961	Five basic problems are associated with microscale circuits: power dissipation, thermal generation and its effects on component packing density, compatibility, adjustability and reliability.	J. J. Suran
Transistorized Electronic Analog Multiplier	Rev Sc Instmnts Feb 1961	The exponential current-voltage characteristic of the input of a grounded base junction transistor is utilized to construct an analog multiplier.	S. Deb J. K. Sen
Method of Measuring and Controlling Evaporation Rates During the Production of Thin Films in Vacuum	Rev Sc Instmnts Feb 1961	A "nude" ionization gauge is used. This method differs from others in that it discriminates between the ions of the vapor and those resulting from the background pressure in the vacuum system.	H. Schwarz
Reduction of Misalignment Voltage in Hall Crystals	Rev Sc Instmnts Feb 1961	A method has been developed by which Hall probes can be aligned electrically, rather than mechanically, as has been done in the past.	C. Wood O. Tischler G. F. Schroeder
The Design of High-Stability D.C. Amplifiers	Semiconductor Prods Feb 1961	A new circuit is shown that has, with unselected transistors, a drift referred to the input of the order of 10 $\mu V/°C$.	P. J. Beneteau
A Survey of Semiconductor Devices and Circuits in Computers, Part III.	Semiconductor Prods Feb 1961	Devices such as the unijunction transistor, p-n-p-n type structures, the tunnel diode, and micromodular types are discussed. Parametric phase-locked oscillators are also analyzed.	V. A. Marsocci
Diode Parametric Amplifiers-Principles and Experiments, Part 2.	Semiconductor Prods Feb 1961	Considerations are given of a number of experimental, low-noise amplifiers.	E. D. Reed
A Review of the Transistor Chopper	Semiconductor Prods Feb 1961	Characteristics, and design circuits are presented.	W. S. Massey
About the Electrical Parameters of Some Types of Selenium Rectifiers	Sov Phys Solid State Jan 1961	In cadmiated selenium rectifiers satisfactory electron hole junctions can be obtained by using cadmium layers $2.4x10^{-5}$ cm thick.	L. Kh. Geller P. V. Sharavskii
Circuit for Measuring and Recording the Resistance of Semiconductors in Coordinates LogR=f(1/T)	Sov Phys Solid State Jan 1961	A combination of logarithmic and hyperbolic amplifiers is used to obtain direct measurements of the stated expression.	L. G. Sapogin V. M. Ivko
Semiconducting Properties of the $AgFeTe_2$ Phase	Sov Phys Solid State Jan 1961	A phase change in $AgFeTe_2$ at 150°C cause discontinuities in electrical properties and Hall coefficient. The mechanism of the change is discussed.	E. L. Shtrum
Concerning a Rapid Method of Precise Measurements of Thermal EMF of Semiconductors	Sov Phys Solid State Jan 1961	A device for measuring the differential thermal EMF of semiconductors on specimens of any shape in the range 25 to 150°C.	O. V. Emelyanenko F. P. Kesamanly
The Investigation of the Characteristics of Germanium Diodes	Sov Phys Solid State Jan 1961	The static and dynamic characteristics of thermistors and germanium rectifiers in the reverse direction are considered.	J. M. Senderikhin P. V. Sharauskii
Contribution to the Theory of Germanium Diode Breakdown	Sov Phys Solid State Jan 1961	The reverse characteristics of germanium point contact and junction diodes are considered.	I. M. Senderikain
Certain Properties of Thallium Selenide Monocrystals	Sov Phys Solid State Jan 1961	Empirical determinations of the magnitude and thermal dependence of electrical conductivity and Hall effect in TlSe monocrystals are discussed.	G. A. Akhundov G. B. Abdullaev G. D. Guseinov
Certain Properties of the CdSb-ZnSb System	Sov Phys Solid State Jan 1961	A study of the electrical conductivity, thermoelectric power, Hall constant, and thermal conductivity is described.	I. M. Pilot Et al
Comparative Investigation of Magnetoconcentration and Photoelectric Methods of Measuring the Surface Recombination Rate	Sov Phys Solid State Jan 1961	Method of measurement based upon the magnetoconcentration effect is proposed as the most accurate.	O. V. Sorokin B. T. Tuseev

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Determination of Recombination Constants From Spectral Characteristics of p-n Junction Photocells. II	Sov Phys Solid State Jan 1961	Determination of absorption coefficient, reflectivity, internal photoeffect quantum yield, and short circuit current per incident quantum, permits calculation of recombination constants.	G. B. Dubrovskii V. K. Subashiev
Investigation of the Kinetics of Fast Surface States In Germanium	Sov Phys Solid State Jan 1961	A study of field effect and photoconductivity kinetics in high resistivity n- and p-type germanium.	V. G. Litovchenko V. I. Lyashenko
Effect of a Magnetic Field on Heat Conduction of Indium Antimonide	Sov Phys Solid State Jan 1961	The thermal conductivity of pure samples of InSb at low temperatures does not change in the presence of a magnetic field because of the small electron fraction of thermal conductivity in this temperature region.	D. Kh. Amirkhanova R. I. Bashirov
Absorbtion of InfraRed Radiation by Electrons in p-Type Silicon	Sov Phys Solid State Jan 1961	A discussion of infrared absorption on the basis of the scattering of electrons by atomic oscillatrions.	V. A. Yakovler
The Effect of Trapping Levels in Semiconductors on Steady State Photoconductivity and Nonequilibrium Carrier Lifetime	Sov Phys Solid State Jan 1961	A discussion of the effects of trapping levels for high and low level injection and high and low densities of recombination centers.	A. A. Grinberg L. G. Paritzkii S. M. Ryrkin
The Effect of Fast Electron Bombardment on the Electrical Conductivity of Silicon and the Dependence of the Rate of Defect Formation on the Orientation of a Crystal with Respect to the Electron Beam	Sov Phys Solid State Jan 1961	Threshold energies necessary to produce stable structural defects in silicon are computed from data.	V. S. Vavilov Et al
Effect of Linear Dislocations on Carrier Recombination in Hole Conducting Germanium	Sov Phys Solid State Jan 1961	The hyperbolic function relating lifetime to dislocation density indicates that in p-type germanium each linear dislocation acts as a recombination.	M. I. Iglitsyn L. I. Kolesnik
Effect of Surface Recombination Rate and Absorption Coefficient on Transient Characteristics of Photodiodes	Sov Phys Solid State Jan 1961	An expression is developed for the transient photo-diode characteristic in the photo-diode operating region for any value of absorption coefficient and surface recombination rate and for any type of generation and surface state.	A. A. Grinberg N. B. Stokan

Source Directory—OTS: Office of Technical Services, Dept of Commerce, Wash. 25, D. C.; MDF: Morris D. Friedman, Inc., P. O. Box 35, West Newton 65, Mass.; LC: Photoduplication Service, Publication Board Project, Library of Congress, Wash. 25, D. C.; SLA: SLA Translations Center, the John Crerar Library, 86 E. Randolph St., Chicago 1, Ill.

Scientific-Technical Conference on the use of Semiconducting Instruments	Tech Trans Feb 14, 1961	Translation of Izvestiya V(ysshikh(U(chebnykh) Z(avedeniy). Radiotekhnika (USSR) 1960, V. 3, no. 1, p. 133-134. Order from MDF $2.00, MDF RECON-4.	O. M. Gaplichuk
The Effect of Frequency on the Rectifying Properties of Semiconductor Diodes with a Small Alternating Voltage	Tech Trans Feb 14, 1961	Translation of Zhurnal Tepnicheskoy Fiziki (USSR) 1955, V. 25, no. 6, p. 1111-1123. It is shown that the frequency characteristics of a small rectified current in semiconductor diodes with a high degree of ionization of the impurities and with significant electrical conductivity may be explained by the existence of a p-n junction capacitance which is provided both by the injection of charge carriers and by the bias current. Order from LC or SLA $3.30, 61-15068.	A. G. Kalashnikov N. A. Penin
Thermoelectricity	Tech Trans Feb 14, 1961	117 refs. OTS Selective Bibliography SB-432. A bibliography of reports listed in the two OTS monthly abstract journals, U.S. Govt Res Repts and Tech Trans. This bibliography includes PB reports, AEC reports, and translations on thermoelectricity added to the OTS collection during the period 1945 to October 1960. Order from OTS, $0.10, OTS SB-432.	Office of Tech Svcs Dept of Commerce
Thermistors and Resistors	Tech Trans Feb 14, 1961	118 refs. OTS Selective Bibliography SB-429. A bibliography of reports listed in the two OTS monthly abstract journals, U. S. Govt Res Repts and Tech Trans. Includes reports added to the OTS collection during the period 1950 to Sept. 1960. Order from OTS, $0.10, OTS SB-429.	Office of Tech Svcs Dept of Commerce
Transistors (Supplement to CRT-310)	Tech Trans Feb 14, 1961	210 refs. OTS Bibliography SB-433. A bibliography of reports listed in the two OTS monthly abstract journals, U.S. Govt Res Repts and Tech Trans. Reports included in this bibliography were added to the OTS collection during the period June 1959 to September 1960. Order from OTS, $0.10, OTS SB-433.	Office of Tech Svcs Dept of Commerce
Antimony, Bismuth, Gallium, Indium, Selenium, and Tellurium	Tech Trans Feb 28, 1961	266 refs. OTS Selective Bibliography SB-433. A bibliography of reports listed in the two OTS monthly abstract journals, U.S. Govt Res Repts and Tech Trans. This bibliography includes reports added to the OTS collection during the period 1950 to October 1960. Order from OTS, $0.10, OTS SB-438.	Office of Tech Svcs Dept of Commerce
Parametric Amplifiers	Tech Trans Feb 28, 1961	Trans of (NTZ) Nachrichtentechnische Zeitschrift (West Ger.) 1960, V. 13, no. 2, p. 57-63. The theory and techniques of parametric amplifiers which use capacitive nonlinearity (varactors) are reviewed. Order from SLA, $4.80, 61-10121.	H. Urbarz
On the Direct Production of Cold Because of Solar Energy by Using Semiconductors	Tech Trans Feb 28, 1961	Translation of Akademiya Nauk Uzbekskoy SSR Tashkent. Izvestiya. Seriya Fiziko Matematicheskikh Nauk, 1960, no. 3, p. 52-55. Order from MDF $3.00, MDF P-154.	I. N. Pomazanov P. L. Tikhomirov
Effect of a Barrier (or Anti-Depletion) Layer at a Metal-Semiconductor Contact on the Volt-Ampere Characteristics of the P-N Junction	Tech Trans Feb 28, 1961	Translation of Akademiya Nauk Uzbekskoy SSR Tashkent. Seriya Fiziko Matematicheskikh Nauk, 1959, no. 6, p. 27-40. Order from MDF $9.00, MDF A-156.	D. A. Aronov G. M. Avak'yank
Electric Conductivity of Thin Gold Films Deposited on a Substrate of Silicon	Tech Trans Feb 28, 1961	Translation of Academie des Sciences (Paris). Comptes Renders (France) 1960, V.250, no. 9, p. 1615-1617. The electrical conductivity of these films is particularly sensitive to the effect of certain gases, and appreciable differences from ohms law are observed at the regular temperature. Order from SLA $1.80, 61-10273.	H. Damany
A Calculation of the Galvano and Thermo-Magnetic Effects in Semiconductors, Taking account of the "Entrainment" Effect.	Tech Trans Feb 28, 1961	Translation of Akademiya Nauk Uzbekskoy SSR Tashkent. Izvestiya. Seriya Fiziko-Matematicheskikh Nauk 1959, no. 6, p. 52-59. Order from MDF $5.00, MDF D-145.	Ye. Dzhaksimov

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Application of a Model of a Semiconductor with One Impurity Level to the Explanation of the Effects of Photoactivation and the Quenching Photoconductivity	Tech Trans Feb 28, 1961	Translation of Akademiya Nauk Uzbekskoy SSR. Izvestiya. Seria Fiziko-Matematicheskikh Nauk, 1959, no. 6, p. 60-71. Order from MDF $7.50, MDF L-134.	A. Yu. Leyderman P. M. Karageorgiy-Alkalayev
Semiconductors (Supplement to CTR-340)	Tech Trans Feb 28, 1961	A bibliography of reports listed in US Govt Res Repts and Tech Translations during the period April 1950 to October 1960. Order from OTS $0.10, OTS. SB-435.	Office of Tech Svcs Dept of Commerce
Temperature Dependence of the Conductivity of Amorphous Germanium Films Deposited by Vaporization	Tech Trans Feb 28, 1961	Trans of Zeitschrift für Angewandte Physik (W. Ger) 1959, V. 11, no. 7, p. 277-283. Resistance measurements were made for Ge films deposited by vaporization in a high vacuum at 20° to 600°C. Order From SLA $4.80, 61-10319.	H. Richter R. Schneider
Luminescence of Zinc Oxide-an Electronic Semiconductor	Tech Trans Feb 28, 1961	Translation of Zhurnal Eksperimental'noy i Teoriticheskoy Fiziki (USSR) 1952, V. 23, no. 6, p. 712-719. Another translation is available from SLA as RT-1775. The hypothesis that zinc atoms are responsible only for the dark conductivity in ZnO and that Zn + ions are the luminescence centers is advanced. Order from LC or SLA, $3.30, 60-16509.	F. I. Vergunas G. A. Konovalov
Study of Noise in Semiconductors and Semiconductor Devices	US Govt Res Repts Dec 11 1960 LC $33.30 PB139069	Methods of measuring noise at liquid helium temperatures is discussed.	A. VanderZiel
Galvanomagnetic Properties of Lead Sulphide, Lead Selenide, and Lead Telluride Between 4.2°K and Room Temperature	US Govt Res Repts Dec 11 1960 LC $31.80 PB143318	No abstract.	R. S. Allgaier
Infrared Scattering Study	US Govt Res Repts Dec 11, 1960 LC $9.30 PB142964	Structural imperfections in silicon single crystals are studied by infrared scattering.	G. H. Schwuttke
A 100 db Microwave Semiconductor Switch	US Govt Res Repts Feb 10, 1961 LC $3.30 PB 152348	A dual diode microwave switch having more than 100 db switched attenuation, low insertion loss, and switching time of 3×10^{-7} seconds is described.	D. W. Feldman B. R. McAvoy
Influence of Conductivity Gradients on Galvanomagnetic Effects in Semiconductors	US Govt Res Repts Feb 10, 1961 LC $3.30 PB 152760	The solution to a boundary value problem is used to predict the effect of carrier concentration gradients on magnetoresistance.	R. T. Bate A. C. Beer
Effects of Electron Bombardment Rate on Conductivity of N-Type Germanium	US Govt Res Repts Feb 10, 1961 LC $4.80 PB 152918	A decrease in conductivity after irradiation of six samples is observed to be strongly dependent upon the rate of irradiation.	R. A. Goldstein
Investigation of Integrally Composed Variable Energy Gap Pholovoltaic Solar Energy Converter	US Govt Res Repts Feb 10, 1961 LC $7.80 PB 149705	The efficiency and characteristics of multiple energy gap cells is compared and contrasted with efficiency and characteristics of conventional single gap cells.	L. E. Stone J. E. Powderly W. E. Medcalf
The Diffusion Rate of Li in Si at Low Temperature	US Govt Res Repts Feb 10, 1961 LC $3.30 PB 149063	The diffusion constant of lithium in silicon in the temperature range 25° to 125°C is determined by utilizing the ion drift in the electric field of an n-p junction.	E. M. Pell
Solid State Research	US Govt Res Repts Feb 10, 1961 LC $15.30 PB 153251	A quarterly progress reports including magnetic properties of matter, semiconductor components and device design, etc.	Lincoln Lab MIT
Study of Surfaces in Semiconductor Devices	US Govt Res Repts Feb 10 1961 LC $7.80 PB 149667	The effects upon electrical properties of silicon diode surfaces which result from diffusion of impurities into the surface during oxidation are discussed.	A. L. Harrington M. F. Millea
Transistor Preamplifier for Neutron Monitors	US Govt Res Repts Feb 10. 1961 LC $3.30 HW 64698	An A.E.C. Report.	P. R. Kelly
Application of Solid State Devices to Nuclear Plant Technology	US Govt Res Repts Feb 10, 1961 LC $1.80 KAPL-M-RFS-I	An A.E.C. Report.	R. F. Shea
Large Area Germanium Surface Barrier Counters	US Govt Res Repts Feb 10 1961 LC $4.80 ORNL 2877	An A.E.C. Report.	F. J. Walter et al.
Transistors Applied To an FM-FM Airborne Radio Telemetry System	US Govt Res Repts Feb 10, 1961 LC $12.30 SCTM 107-56-52	An A.E.C. Report.	R. Gablehouse
Transistorized Pulse Counting Equipment	US Govt Res Repts Feb 10, 1961 OTS $0.75 Y1313	An A.E.C. Report.	J. J. Henry
Transistorized Telegraph Telephone Terminal AN/TCC-29	US Govt Res Repts Feb 10, 1961 LC $19.80 PB 152513	Service test models of TCC-14 equipment are designed and developed.	H. Levick S. Feldman
Intrinsic Barrier Transistor Techniques (Silicon)	US Govt Res Repts Feb 10, 1961 LC $6.30 PB 152559	Work on lumped constant transistor oscillators suitable for use in the 70 to 300 megacycle band is described.	K. K. Kanazawa R. C. Neville W. E. Roach
Transistors (Supplement to CTR-310)	US Govt Res Repts Feb 10, 1961 OTS $0.10 SB-433	A bibliography of reports.	OTS
Dial Telephone Switching Circuits	US Govt Res Repts Feb 10 1961 LC $12.30 PB153236	A theoretical study of the applicability of transistors in a dial system.	(No Author Cited) U. of Penn School of E. E.
A Transistorized Negative Feedback High Q Filter	US Govt Res Repts Feb 10, 1961 LC $7.80 PB 148984	A transistor current amplifier and a bridged-tee network are employed in a negative feedback arrangement to provide a filter with a 100 kcps center frequency and a 30 cps band pass.	J. M. Brown
The Effects of Nuclear Radiation on Power Transistors	US Govt Res Repts Feb 10, 1961 LC $4.80 PB 152804	Homogeneous base germanium power transistors were exposed to nuclear radiation. Device parameter changes are discussed from the empirical and theoretical points of view.	F. Gordon Jr.

CHARACTERISTICS CHARTS OF NEW DIODES and RECTIFIERS

MANUFACTURERS

AEG—	Allgemeine Elekticitats-Gesellschaft
ASC—	American Semiconductor Corp.
AMP—	Amperex Electronic Corp.
AEI—	Associated Electrical Industries, Ltd.
ATLB—	Associated Transistors, Ltd.
BEN—	Bendix Corp.
BER—	Berkshire Corp.
BOM—	Bomac Labs
BRA—	Bradley Semiconductor Corp.
BRI—	Britton Electronics Corp.
CBS—	CBS Electronics
CDC—	Continental Device Corp.
CDLF—	Compagnie des Lampes
COD—	Computer Diode Corp.
COL—	Columbus Electronics Corp.
CON—	Controls Co., of America
CTP—	Clevite Transistor Products, Inc.
CSF—	(Cosem) Cie Generale des Semi-Conducteurs
DEL—	Delco Radio
DES—	Delta Semiconductors, Inc.
DIC—	Dickson Electronics Corp.
EEVB—	English Electric Valve Co., Ltd.
ERI—	Erie Resistor Corp.
ESP—	Espey Mfg. and Electronics Corp.
FAN—	Fansteel Metallurgical Corp.
FERB—	Ferranti Ltd.
FSC—	Fairchild Semiconductor Corp.
GAH—	Gahagan, Inc.
GECB—	General Electric Co., Ltd.
GE—	General Electric Company, Semiconductor Div.
GELC—	Canadian General Electric Co.
GIC—	General Instrument Corp.
HAFO—	Institutet for Halvedarforskning
HITJ—	Hitachi Ltd., Mushashi Works
HUG—	Hughes Products Division
ITC—	Industro Transistor Corp.
IDC—	International Diode Corp.
INRB—	International Rectifier Co., Ltd.
INRC—	International Rectifier Corp.
IRC—	International Resistance Co.
ITT—	International Tel. & Tel. Corp.
KEM—	Kemtron Electron Products, Inc.
KOKJ—	Kobe Kogyo Corp.
MAL—	P. R. Mallory & Co., Inc.
MATJ—	Matushita Electronics Corp.
MSC—	MicroSemiconductor Corp.
MIC—	Microwave Associates, Inc.
MISI—	Mistral
MOT—	Motorola, Inc
MUL—	Mullard, Ltd.
NSLC—	National Semiconductors, Ltd.
NAE—	North American Electronics
NPC—	Nucleonic Products Co., Inc.
OHM—	Ohio Semiconductor Inc.
PHI—	Philco Corp. Lansdale Div., Semiconductor Operations
PHIN—	Philips Gloeilampenfabrieken
PLEB—	The Plessey Co.
PRI—	Princeton Electronics Corp.
PSI—	Pacific Semiconductors, Inc.
RADF—	La Radiotechnique Div. Tubes Electroniques
RAY—	Raytheon Company
RCA—	Radio Corporation of America, Semiconductor Div.
RDR—	Radio Development and Research Corp.
RHE—	Rheem Semiconductor Corp.
HSD—	Hoffman Semiconductor Division
ROSG—	Dr. Ing. Rudolph Rost
SAR—	Sarkes Tarzian, Inc., Rectifier Division
SCN—	Semicon, Inc.
SEM—	Semi-Elements Inc.
SIE—	Siemens & Halske Aktiengesellschaft
SIL—	Silicon Transistor Corp.
SGSI—	Societa Generale Semiconduttori
SLA—	Slater Electric Inc.
SOIF—	Societe Industrial de Liaisons
SOD—	Solitron Devices, Inc.
SONY—	Sony Corp.
SSD—	Sperry Semiconductor Division
SSP—	Solid State Products, Inc.
STC—	Shockley Transistor Corp.
STCB—	Standard Telephone & Cables, Ltd.
STCA—	Standard Tel. and Cables Pty, Ltd.
SYL—	Sylvania Electric Products, Inc.
SYN—	Syntron Co.
TEX—	Texas Research Assoc.
TFKG—	Telefunken, Ltd.
TI—	Texas Instruments Incorporated
TKD—	Tekade
TRA—	Transitron Electronic Corp.
TUN—	Tung-Sol Electric, Inc.
TSC—	Trans-Sil Corp.
UCI—	United Components
UNI—	Unitrode Transistor Prods., Corp.
USS—	U. S. Semiconductor Products, Inc.
VIC—	Vickers Inc.
WEC—	Western Electric Co.
WESB—	Westinghouse Brake and Signal Co., Ltd.
WEST—	Westinghouse Electric Corp.

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA)	(E_f volts)	MAX. D.C. OUTPUT CURRENT[4] (amps)	@ T (°C)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_b @ T (uA)	(E_b volts)	(°C)	MFR. (See code at start of charts)
1N3208	2	Si	50	50	40A	1.5	15	150	1.5	1000	50	25	MOT
1N3209	2	Si	100	100	40A	1.5	15	150	1.5	1000	100	25	MOT
1N3210	2	Si	200	200	40A	1.5	15	150	1.5	1000	200	25	MOT
1N3211	2	Si	300	300	40A	1.5	15	150	1.5	1000	300	25	MOT
1N3212	2	Si	400	400	40A	1.5	15	150	1.5	1000	400	25	MOT
1N3282	1	Si	1000	1000	100	2.5	.10	25	2.5	1.0	1000	25	MOT
1N3283	1	Si	1500	1500	100	2.5	.10	25	2.5	1.0	1500	25	MOT
1N3284	1	Si	2000	2000	100	2.5	.10	25	2.5	1.0	2000	25	MOT
1N3285	1	Si	2500	2500	100	2.5	.10	25	2.5	1.0	2500	25	MOT
1N3286	1	Si	3000	3000	100	2.5	.10	25	2.5	1.0	3000	25	MOT
A50	1	Si	50	50			.75A	100A	.50	250	50	100A	MAL
A100	1	Si	100	100			.75A	100A	.50	250	50	100A	MAL
A200	1	Si	200	200			.75A	100A	.50	250	50	100A	MAL
A300	1	Si	300	300			.75A	100A	.50	250	50	100A	MAL
A400	1	Si	400	400			.75A	100A	.50	250	50	100A	MAL
A500	1	Si	500	500			.75A	100A	.50	250	50	100A	MAL
A600	1	Si	600	600			.75A	100A	.50	250	50	100A	MAL
CS32B	5	Si	25				19.5	75C	2.2				WESB
CS32C	5	Si	50				19.5	75C	2.2				WESB
CS32D	5	Si	75				19.5	75C	2.2				WESB
CS32E	5	Si	100				19.5	75C	2.2				WESB
CS32G	5	Si	150				19.5	75C	2.2				WESB
CS32J	5	Si	200				19.5	75C	2.2				WESB
CS32K	5	Si	250				19.5	75C	2.2				WESB
CS32L	5	Si	300				19.5	75C	2.2				WESB
CS32M	5	Si	350				19.5	75C	2.2				WESB
CS32N	5	Si	400				19.5	75C	2.2				WESB
MD04	1	Si	40		10	1.0	.05	25		100	30	150	GIC
PS5300	1	Si	225	275	400	1.0	.40	25		10	225	150	PSI
PS5301	1	Si	300	360	400	1.0	.40	25		10	300	150	PSI
PS5302	1	Si	400	480	400	1.0	.40	25		15	400	150	PSI
PS5303	1	Si	500	600	400	1.0	.40	25		15	500	150	PSI
PS5304	1	Si	600	720	400	1.0	.40	25		15	600	150	PSI
S1AR2	2	Si	100				1.0	30A	.60				WESB
S2AR2	2	Si	200				1.0	30A	.60				WESB

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA)	(E_f volts)	MAX. D.C. OUTPUT CURRENT[4] (amps)	@ T (°C)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_b @ T (uA)	(E_b volts)	(°C)	MFR. (See code at start of charts)
S3AR2	2	Si	300				1.0	30A	.60				WESB
S4AR2	2	Si	400				1.0	30A	.60				WESB
S5AR2	2	Si	500				1.0	30A	.60				WESB
S6AR2	2	Si	600				1.0	30A	.60				WESB
S8AR2	2	Si	800				1.0	30A	.60				WESB
S10AR2	2	Si	1000				1.0	30A	.60				WESB
S12AR2	2	Si	1200				1.0	30A	.60				WESB
S15AR2	2	Si	1500				1.0	30A	.60				WESB
VB400	6	Si	400	400			.75A	100A	.50	250	50	100A	MAL
VB600	6	Si	600	600			.75A	100A	.50	250	50	100A	MAL

UNDER USE
1 - General Purpose
2 - Power Rectifier
3 - Magnetic Amplifier
5 - Controlled Rectifier
6 - Dual Rectifier
7 - Controlled Forward Conductance

OTHER
4 - For half wave resistance lead average over 1 cycle

REVERSE CURRENT
☑ - Dynamic

MFR
6 - Available in Stack form from Mfr.

8 - High Voltage Rectifier
9 - Bridge Rectifier
☑ - Revised Specifications
Ø - Insulated Base
Δ - Direct Tube Replacement
† - Pair
# - Forced Air Cooling

FOLLOWING ANY TEMPERATURE READING
A - Ambient
C - Case
J - Junction
S - Storage
Δ - Inlet temperature of coolant

CHARACTERISTICS CHART of SILICON ZENER or AVALANCHE DIODES

TYPE NO.	Zener or Avalanche Voltage Range MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Dynamic Impedance Z @ I_z (ohms)	(ma)	MAX. DISS. (mw)	TEMP. CO-EFFICIENT %/°C	MFR. {See code at start of chart}
1N3305*	5.44	8.16	1850	.40	500	50000	.040	DIC
1N3305A*	6.12	7.48	1850	.40	500	50000	.040	DIC
1N3305B*	6.46	7.14	1850	.40	500	50000	.040	DIC
1N3306*	6.00	9.00	1700	.50	250	50000	.045	DIC
1N3306A*	6.75	8.25	1700	.50	250	50000	.045	DIC
1N3306B*	7.13	7.88	1700	.50	250	50000	.045	DIC
1N3307*	6.56	9.84	1500	.60	250	50000	.048	DIC
1N3307A*	7.38	9.02	1500	.60	250	50000	.048	DIC
1N3307B*	7.79	8.61	1500	.60	250	50000	.048	DIC
1N3308*	7.28	10.92	1370	.70	250	50000	.050	DIC
1N3308A*	8.19	10.01	1370	.70	250	50000	.050	DIC
1N3308B*	8.65	9.56	1370	.70	250	50000	.050	DIC
1N3309*	8.00	12	1200	.80	250	50000	.055	DIC
1N3309A*	9.00	11	1200	.80	250	50000	.055	DIC
1N3309B*	9.50	10.50	1200	.80	250	50000	.055	DIC
1N3310*	8.80	13.20	1100	.90	250	50000	.060	DIC
1N3310A*	9.90	12.1	1100	.90	250	50000	.060	DIC
1N3310B*	10.45	11.55	1100	.90	250	50000	.060	DIC
1N3311*	9.60	14.4	1000	1.0	250	50000	.065	DIC
1N3311A*	10.8	13.2	1000	1.0	250	50000	.065	DIC
1N3311B*	11.4	12.6	1000	1.0	250	50000	.065	DIC
1N3312*	10.40	15.6	960	1.1	250	50000	.065	DIC
1N3312A*	11.7	14.3	960	1.1	250	50000	.065	DIC
1N3312B*	12.35	13.65	960	1.1	250	50000	.065	DIC
1N3313*	11.20	16.8	890	1.2	250	50000	.070	DIC
1N3313A*	12.6	15.4	890	1.2	250	50000	.070	DIC
1N3313B*	13.30	14.7	890	1.2	250	50000	.070	DIC
1N3314*	12	18	830	1.4	250	50000	.070	DIC
1N3314A*	13.5	16.5	830	1.4	250	50000	.070	DIC
1N3314B*	14.25	15.75	830	1.4	250	50000	.070	DIC
1N3315*	12.80	19.2	780	1.6	250	50000	.070	DIC
1N3315A*	14.4	17.6	780	1.6	250	50000	.070	DIC
1N3315B*	15.20	16.8	780	1.6	250	50000	.070	DIC
1N3316*	13.60	20.4	740	1.8	250	50000	.075	DIC
1N3316A*	15.3	18.7	740	1.8	250	50000	.075	DIC
1N3316B*	16.15	17.85	740	1.8	250	50000	.075	DIC
1N3317*	14.40	21.6	700	2.0	250	50000	.075	DIC
1N3317A*	16.2	19.8	700	2.0	250	50000	.075	DIC
1N3317B*	17.10	18.90	700	2.0	250	50000	.075	DIC
1N3318*	15.20	22.8	660	2.2	250	50000	.075	DIC
1N3318A*	17.1	20.9	660	2.2	250	50000	.075	DIC
1N3318B*	18.05	19.95	660	2.2	250	50000	.075	DIC
1N3319*	16	24	630	2.4	250	50000	.075	DIC
1N3319A*	18	22	630	2.4	250	50000	.075	DIC
1N3319B*	19	21	630	2.4	250	50000	.075	DIC
1N3320*	17.60	26.4	570	2.5	250	50000	.080	DIC
1N3320A*	19.8	24.2	570	2.5	250	50000	.080	DIC
1N3320B*	20.9	23.1	570	2.5	250	50000	.080	DIC
1N3321*	19.20	28.8	520	2.6	250	50000	.080	DIC
1N3321A*	21.6	26.4	520	2.6	250	50000	.080	DIC
1N3321B*	22.8	25.2	520	2.6	250	50000	.080	DIC
1N3322*	20	30	500	2.7	250	50000	.080	DIC
1N3322A*	22.5	27.5	500	2.7	250	50000	.080	DIC
1N3322B*	23.75	26.25	500	2.7	250	50000	.080	DIC
1N3323*	21.60	32.4	460	2.8	250	50000	.085	DIC
1N3323A*	24.3	29.7	460	2.8	250	50000	.085	DIC
1N3323B*	25.65	28.35	460	2.8	250	50000	.085	DIC
1N3324*	24	36	420	3.0	300	50000	.085	DIC
1N3324A*	27	33	420	3.0	300	50000	.085	DIC
1N3324B*	28.5	31.5	420	3.0	300	50000	.085	DIC

UNDER TYPE NO.
☑ - Revised Specifications Δ - Also available with ±5 per cent tolerance
Ø - Double Anode Type † - Reference Amplifier
* - Developmental Type # - Available with reverse polarity

CHARACTERISTICS CHART of SILICON ZENER or AVALANCHE DIODES

TYPE NO.	Zener or Avalanche Voltage Range MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Dynamic Impedance Z @ I_z (ohms)	(ma)	MAX. DISS. (mw)	TEMP. CO-EFFICIENT %/°C	MFR. {See code at start of chart}
1N3325*	26.40	39.6	380	3.2	300	50000	.085	DIC
1N3325A*	29.7	36.3	380	3.2	300	50000	.085	DIC
1N3325B*	31.35	34.65	380	3.2	300	50000	.085	DIC
1N3326*	28.80	43.2	350	3.5	300	50000	.085	DIC
1N3326A*	32.4	39.6	350	3.5	300	50000	.085	DIC
1N3326B*	34.2	37.8	350	3.5	300	50000	.085	DIC
1N3327*	31.20	46.8	320	4.0	300	50000	.090	DIC
1N3327A*	35.1	42.9	320	4.0	300	50000	.090	DIC
1N3327B*	37.05	40.95	320	4.0	300	50000	.090	DIC
1N3328*	34.40	51.6	290	4.5	400	50000	.090	DIC
1N3328A*	38.7	47.3	290	4.5	400	50000	.090	DIC
1N3328B*	40.85	45.15	290	4.5	400	50000	.090	DIC
1N3329*	36	54	280	4.5	400	50000	.090	DIC
1N3329A*	40.5	49.5	280	4.5	400	50000	.090	DIC
1N3329B*	42.75	47.25	280	4.5	400	50000	.090	DIC
1N3330*	37.60	56.4	270	5.0	400	50000	.090	DIC
1N3330A*	42.3	51.7	270	5.0	400	50000	.090	DIC
1N3330B*	44.65	49.35	270	5.0	400	50000	.090	DIC
1N3331*	40	60	250	5.0	500	50000	.090	DIC
1N3331A*	45	55	250	5.0	500	50000	.090	DIC
1N3331B*	47.5	52.5	250	5.0	500	50000	.090	DIC
1N3332*	40.80	61.2	245	5.2	500	50000	.090	DIC
1N3332A*	45.9	56.1	245	5.2	500	50000	.090	DIC
1N3332B*	48.45	53.55	245	5.2	500	50000	.090	DIC
1N3333*	41.60	62.4	240	5.5	500	50000	.090	DIC
1N3333A*	46.8	57.2	240	5.5	500	50000	.090	DIC
1N3333B*	49.4	54.6	240	5.5	500	50000	.090	DIC
1N3334*	44.80	67.2	220	6.0	500	50000	.090	DIC
1N3334A*	50.4	61.6	220	6.0	500	50000	.090	DIC
1N3334B*	53.2	58.8	220	6.0	500	50000	.090	DIC
1N3335*	49.60	74.4	200	7.0	600	50000	.090	DIC
1N3335A*	55.8	68.2	200	7.0	600	50000	.090	DIC
1N3335B*	58.9	65.1	200	7.0	600	50000	.090	DIC
1N3336*	54.40	81.6	180	8.0	600	50000	.090	DIC
1N3336A*	61.2	74.8	180	8.0	600	50000	.090	DIC
1N3336B*	64.6	71.4	180	8.0	600	50000	.090	DIC
1N3337*	60	90	170	9.0	600	50000	.090	DIC
1N3337A*	67.5	82.5	170	9.0	600	50000	.090	DIC
1N3337B*	71.25	78.75	170	9.0	600	50000	.090	DIC
1N3338*	65.60	98.4	150	11	700	50000	.090	DIC
1N3338A*	73.8	90.2	150	11	700	50000	.090	DIC
1N3338B*	77.9	86.1	150	11	700	50000	.090	DIC
1N3339*	72.80	109.2	140	15	800	50000	.090	DIC
1N3339A*	81.9	100.1	140	15	800	50000	.090	DIC
1N3339B*	86.45	95.55	140	15	800	50000	.090	DIC
1N3340*	80	120	120	20	900	50000	.090	DIC
1N3340A*	90	110	120	20	900	50000	.090	DIC
1N3340B*	95	105	120	20	900	50000	.090	DIC
AV2010	9.8	10.2	50	5.0	50	1000		ASC
AV2012	11.76	12.24	50	6.0	50	1000		ASC
AV2013	12.74	13.26	50	6.0	50	1000		ASC
AV2014	13.72	14.28	50	9.0	50	1000		ASC
AV2015	14.7	15.3	50	9.0	50	1000		ASC
AV2016	15.68	16.32	50	9.0	50	1000		ASC
AV2017	16.66	17.34	50	14	50	1000		ASC
AV2018	17.64	18.36	50	14	50	1000		ASC
AV2019	18.62	19.38	50	14	50	1000		ASC
AV2020	19.6	20.4	50	14	50	1000		ASC
AV2021	20.58	21.42	15	20	15	1000		ASC
AV2022	21.56	22.44	15	20	15	1000		ASC
AV2024	23.52	24.48	15	20	15	1000		ASC
AV2025	24.5	25.5	15	20	15	1000		ASC
AV2026	25.48	26.52	15	29	15	1000		ASC
AV2027	26.46	27.54	15	29	15	1000		ASC
AV2028	27.44	28.56	15	29	15	1000		ASC
AV2029	28.42	29.58	15	29	15	1000		ASC
AV2030	29.4	30.6	15	29	15	1000		ASC
AV2031	30.38	31.62	15	40	15	1000		ASC
AV2032	31.36	32.64	15	40	15	1000		ASC
AV2033	32.34	33.66	15	40	15	1000		ASC

CHARACTERISTICS CHART of SILICON ZENER or AVALANCHE DIODES

TYPE NO.	Zener or Avalanche Voltage Range			Dynamic Impedance		MAX. DISS.	TEMP. CO-EFFICIENT	MFR. (See code at start of chart)
	MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Z @ I_z (ohms)	(ma)	(mw)	%/°C	
AV2034	33.32	34.68	15	40	15	1000		ASC
AV2035	34.3	35.7	15	40	15	1000		ASC
AV2036	35.28	36.72	15	40	15	1000		ASC
AV2037	36.26	37.74	15	40	15	1000		ASC
AV2038	37.24	38.76	15	55	15	1000		ASC
AV2039	38.22	39.78	15	55	15	1000		ASC
AV2040	39.2	40.8	15	55	15	1000		ASC
AV2041	40.18	41.82	15	55	15	1000		ASC
AV2042	41.16	42.84	15	55	15	1000		ASC
AV2043	42.14	43.86	15	55	15	1000		ASC
AV2044	43.12	44.88	15	55	15	1000		ASC
AV2045	44.1	45.9	15	76	15	1000		ASC
AV2046	45.08	46.92	15	76	15	1000		ASC
AV2047	46.06	47.94	15	76	15	1000		ASC
AV2048	47.04	48.96	15	76	15	1000		ASC
AV2049	48.02	49.98	15	76	15	1000		ASC
AV2050	49	51	15	76	15	1000		ASC
AV2051	49.98	52.02	15	76	15	1000		ASC
AV2052	50.96	53.04	5.0	107	5.0	1000		ASC
AV2053	51.94	54.06	5.0	107	5.0	1000		ASC
AV2054	52.92	55.08	5.0	107	5.0	1000		ASC
AV2055	53.9	56.1	5.0	107	5.0	1000		ASC
AV2056	54.88	57.12	5.0	107	5.0	1000		ASC
AV2057	55.86	58.14	5.0	107	5.0	1000		ASC
AV2058	56.84	59.16	5.0	107	5.0	1000		ASC
AV2059	57.82	60.18	5.0	107	5.0	1000		ASC
AV2060	58.8	61.2	5.0	107	5.0	1000		ASC
AV2061	59.78	62.22	5.0	107	5.0	1000		ASC
AV2062	60.76	63.24	5.0	107	5.0	1000		ASC
AV2063	61.74	64.26	5.0	155	5.0	1000		ASC
AV2064	62.72	65.28	5.0	155	5.0	1000		ASC
AV2065	63.7	66.3	5.0	155	5.0	1000		ASC
AV2066	64.68	67.32	5.0	155	5.0	1000		ASC
AV2067	65.66	68.34	5.0	155	5.0	1000		ASC
AV2068	66.64	69.36	5.0	155	5.0	1000		ASC
AV2069	67.62	70.38	5.0	155	5.0	1000		ASC
AV2070	68.6	71.4	5.0	155	5.0	1000		ASC
AV2071	69.58	72.42	5.0	155	5.0	1000		ASC
AV2072	70.56	73.44	5.0	155	5.0	1000		ASC
AV2073	71.54	74.46	5.0	155	5.0	1000		ASC
AV2074	72.52	75.48	5.0	155	5.0	1000		ASC
AV2075	73.5	76.5	5.0	155	5.0	1000		ASC
AV2076	74.48	77.52	5.0	155	5.0	1000		ASC
AV2077	75.46	78.54	5.0	155	5.0	1000		ASC
AV2078	76.44	79.56	5.0	220	5.0	1000		ASC
AV2079	77.42	80.58	5.0	220	5.0	1000		ASC
AV2080	78.4	81.6	5.0	220	5.0	1000		ASC
AV2081	79.38	82.62	5.0	220	5.0	1000		ASC
AV2082	80.36	83.64	5.0	220	5.0	1000		ASC
AV2083	81.34	84.66	5.0	220	5.0	1000		ASC
AV2084	82.32	85.68	5.0	220	5.0	1000		ASC
AV2085	83.3	86.7	5.0	220	5.0	1000		ASC
AV2086	84.28	87.72	5.0	220	5.0	1000		ASC
AV2087	85.26	88.74	5.0	220	5.0	1000		ASC
AV2088	86.24	89.76	5.0	220	5.0	1000		ASC
AV2089	87.22	90.78	5.0	220	5.0	1000		ASC
AV2090	88.2	91.8	5.0	220	5.0	1000		ASC
AV2091	89.18	92.82	5.0	330	5.0	1000		ASC
AV2092	90.16	93.84	5.0	330	5.0	1000		ASC
AV2093	91.14	94.86	5.0	330	5.0	1000		ASC
AV2094	92.12	95.88	5.0	330	5.0	1000		ASC
AV2095	93.1	96.9	5.0	330	5.0	1000		ASC
AV2096	94.08	97.92	5.0	330	5.0	1000		ASC
AV2097	95.06	98.94	5.0	330	5.0	1000		ASC
AV2098	96.04	99.96	5.0	330	5.0	1000		ASC
AV2099	97.02	100.98	5.0	330	5.0	1000		ASC
AV2100	98	102	5.0	330	5.0	1000		ASC
AV2105	102.9	107.1	5.0	330	5.0	1000		ASC
AV2110	107.8	112.2	5.0	330	5.0	1000		ASC
AV2115	112.7	117.3	5.0	500	5.0	1000		ASC

CHARACTERISTICS CHART of SILICON ZENER or AVALANCHE DIODES

TYPE NO.	Zener or Avalanche Voltage Range			Dynamic Impedance		MAX. DISS.	TEMP. CO-EFFICIENT	MFR. (See code at start of chart)
	MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Z @ I_z (ohms)	(ma)	(mw)	%/°C	
AV2120	117.6	122.4	5.0	500	5.0	1000		ASC
AV2125	122.5	127.5	5.0	500	5.0	1000		ASC
AV2130	127.4	132.6	5.0	500	5.0	1000		ASC
AV2135	132.3	137.7	5.0	500	5.0	1000		ASC
AV2140	137.2	142.8	5.0	800	5.0	1000		ASC
AV2145	142.1	147.9	5.0	800	5.0	1000		ASC
AV2150	147	153	5.0	800	5.0	1000		ASC
AV2155	151.9	158.1	5.0	800	5.0	1000		ASC
AV2160	156.8	163.2	5.0	800	5.0	1000		ASC
AV2165	161.7	168.3	5.0	800	5.0	1000		ASC
AV2170	166.6	173.4	5.0	1150	5.0	1000		ASC
AV2175	171.5	178.5	5.0	1150	5.0	1000		ASC
AV2180	176.4	183.6	5.0	1150	5.0	1000		ASC
AV2185	181.3	188.7	5.0	1150	5.0	1000		ASC
AV2190	186.2	193.8	5.0	1150	5.0	1000		ASC
AV2195	191.1	198.9	5.0	1150	5.0	1000		ASC
AV2200	196	204	5.0	1150	5.0	1000		ASC
AV4010	9.8	10.2	50	5.0	50	3000		ASC
AV4012	11.76	12.24	50	6.0	50	3000		ASC
AV4013	12.74	13.26	50	6.0	50	3000		ASC
AV4014	13.72	14.28	50	9.0	50	3000		ASC
AV4015	14.7	15.3	50	9.0	50	3000		ASC
AV4016	15.68	16.32	50	9.0	50	3000		ASC
AV4017	16.66	17.34	50	14	50	3000		ASC
AV4018	17.64	18.36	50	14	50	3000		ASC
AV4019	18.62	19.38	50	14	50	3000		ASC
AV4020	19.6	20.4	50	14	50	3000		ASC
AV4021	20.58	21.42	15	20	15	3000		ASC
AV4022	21.56	22.44	15	20	15	3000		ASC
AV4024	23.52	24.48	15	20	15	3000		ASC
AV4025	24.5	25.5	15	20	15	3000		ASC
AV4026	25.48	26.52	15	29	15	3000		ASC
AV4027	26.46	27.54	15	29	15	3000		ASC
AV4028	27.44	28.56	15	29	15	3000		ASC
AV4029	28.42	29.58	15	29	15	3000		ASC
AV4030	29.4	30.6	15	29	15	3000		ASC
AV4031	30.38	31.62	15	40	15	3000		ASC
AV4032	31.36	32.64	15	40	15	3000		ASC
AV4033	32.34	33.66	15	40	15	3000		ASC
AV4034	33.32	34.68	15	40	15	3000		ASC
AV4035	34.3	35.7	15	40	15	3000		ASC
AV4036	35.28	36.72	15	40	15	3000		ASC
AV4037	36.26	37.74	15	40	15	3000		ASC
AV4038	37.24	38.76	15	55	15	3000		ASC
AV4039	38.22	39.78	15	55	15	3000		ASC
AV4040	39.2	40.8	15	55	15	3000		ASC
AV4041	40.18	41.82	15	55	15	3000		ASC
AV4042	41.16	42.84	15	55	15	3000		ASC
AV4043	42.14	43.86	15	55	15	3000		ASC
AV4044	43.12	44.88	15	55	15	3000		ASC
AV4045	44.1	45.9	15	76	15	3000		ASC
AV4046	45.08	46.92	15	76	15	3000		ASC
AV4047	46.06	47.94	15	76	15	3000		ASC
AV4048	47.04	48.96	15	76	15	3000		ASC
AV4049	48.02	49.98	15	76	15	3000		ASC
AV4050	49	51	15	76	15	3000		ASC
AV4051	49.98	52.02	15	76	15	3000		ASC
AV4052	50.96	53.04	5.0	107	5.0	3000		ASC
AV4053	51.94	54.06	5.0	107	5.0	3000		ASC
AV4054	52.92	55.08	5.0	107	5.0	3000		ASC
AV4055	52.9	56.1	5.0	107	5.0	3000		ASC
AV4056	54.88	57.12	5.0	107	5.0	3000		ASC
AV4057	55.86	58.14	5.0	107	5.0	3000		ASC
AV4058	56.84	59.16	5.0	107	5.0	3000		ASC
AV4059	57.82	60.18	5.0	107	5.0	3000		ASC
AV4060	58.8	61.2	5.0	107	5.0	3000		ASC
AV4061	59.78	62.22	5.0	107	5.0	3000		ASC
AV4062	60.76	63.24	5.0	107	5.0	3000		ASC
AV4063	61.74	64.26	5.0	155	5.0	3000		ASC
AV4064	62.72	65.28	5.0	155	5.0	3000		ASC

CHARACTERISTICS CHART of SILICON ZENER or AVALANCHE DIODES

TYPE NO.	Zener or Avalanche Voltage Range MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Dynamic Impedance Z @ I_z (ohms)	(ma)	MAX. DISS. (mw)	TEMP. CO-EFFICIENT %/°C	MFR. {See code at start of chart}
AV4065	63.7	66.3	5.0	155	5.0	3000		ASC
AV4066	64.68	67.32	5.0	155	5.0	3000		ASC
AV4067	65.66	68.34	5.0	155	5.0	3000		ASC
AV4068	66.64	69.36	5.0	155	5.0	3000		ASC
AV4069	67.62	70.38	5.0	155	5.0	3000		ASC
AV4070	68.6	71.4	5.0	155	5.0	3000		ASC
AV4071	69.58	72.42	5.0	155	5.0	3000		ASC
AV4072	70.56	73.44	5.0	155	5.0	3000		ASC
AV4073	71.54	74.46	5.0	155	5.0	3000		ASC
AV4074	72.52	75.48	5.0	155	5.0	3000		ASC
AV4075	73.5	76.5	5.0	155	5.0	3000		ASC
AV4076	74.48	77.52	5.0	155	5.0	3000		ASC
AV4077	75.46	78.54	5.0	155	5.0	3000		ASC
AV4078	76.44	79.56	5.0	220	5.0	3000		ASC
AV4079	77.42	80.58	5.0	220	5.0	3000		ASC
AV4080	78.4	81.6	5.0	220	5.0	3000		ASC
AV4081	79.38	82.62	5.0	220	5.0	3000		ASC
AV4082	80.36	83.64	5.0	220	5.0	3000		ASC
AV4083	81.34	84.66	5.0	220	5.0	3000		ASC
AV4084	82.32	85.68	5.0	220	5.0	3000		ASC
AV4085	83.3	86.7	5.0	220	5.0	3000		ASC
AV4086	84.28	87.72	5.0	220	5.0	3000		ASC
AV4087	85.26	88.74	5.0	220	5.0	3000		ASC
AV4088	86.24	89.76	5.0	220	5.0	3000		ASC
AV4089	87.22	90.78	5.0	220	5.0	3000		ASC
AV4090	88.2	91.8	5.0	220	5.0	3000		ASC
AV4091	89.18	92.82	5.0	330	5.0	3000		ASC
AV4092	90.16	93.84	5.0	330	5.0	3000		ASC
AV4093	91.14	94.86	5.0	330	5.0	3000		ASC
AV4094	92.12	95.88	5.0	330	5.0	3000		ASC
AV4095	93.1	96.9	5.0	330	5.0	3000		ASC
AV4096	94.08	97.92	5.0	330	5.0	3000		ASC
AV4097	95.06	98.94	5.0	330	5.0	3000		ASC
AV4098	96.04	99.96	5.0	330	5.0	3000		ASC
AV4099	97.02	100.98	5.0	330	5.0	3000		ASC
AV4100	98	102	5.0	330	5.0	3000		ASC
AV4105	102.9	107.1	5.0	330	5.0	3000		ASC
AV4110	107.8	112.2	5.0	330	5.0	3000		ASC
AV4115	112.7	117.3	5.0	500	5.0	3000		ASC
AV4120	117.6	122.4	5.0	500	5.0	3000		ASC
AV4125	122.5	127.5	5.0	500	5.0	3000		ASC
AV4130	127.4	132.6	5.0	500	5.0	3000		ASC
AV4135	132.3	137.7	5.0	500	5.0	3000		ASC
AV4140	137.2	142.8	5.0	800	5.0	3000		ASC
AV4145	142.1	147.9	5.0	800	5.0	3000		ASC
AV4150	147	153	5.0	800	5.0	3000		ASC
AV4155	151.9	158.1	5.0	800	5.0	3000		ASC
AV4160	156.8	163.2	5.0	800	5.0	3000		ASC
AV4165	161.7	168.3	5.0	800	5.0	3000		ASC
AV4170	166.6	173.4	5.0	1150	5.0	3000		ASC
AV4175	171.5	178.5	5.0	1150	5.0	3000		ASC
AV4180	176.4	183.6	5.0	1150	5.0	3000		ASC
AV4185	181.3	188.7	5.0	1150	5.0	3000		ASC
AV4190	186.2	193.8	5.0	1150	5.0	3000		ASC
AV4195	191.1	198.9	5.0	1150	5.0	3000		ASC
AV4200	196	204	5.0	1150	5.0	3000		ASC
AV8010	9.8	10.2	50	5.0	50	10000		ASC
AV8012	11.76	12.24	50	6.0	50	10000		ASC
AV8013	12.74	13.26	50	6.0	50	10000		ASC
AV8014	13.72	14.28	50	9.0	50	10000		ASC
AV8015	14.7	15.3	50	9.0	50	10000		ASC
AV8016	15.68	16.32	50	9.0	50	10000		ASC
AV8017	16.66	17.34	50	14	50	10000		ASC
AV8018	17.64	18.36	50	14	50	10000		ASC
AV8019	18.62	19.38	50	14	50	10000		ASC
AV8020	19.6	20.4	50	14	50	10000		ASC
AV8021	20.58	21.42	15	20	15	10000		ASC
AV8022	21.56	22.44	15	20	15	10000		ASC
AV8024	23.52	24.48	15	20	15	10000		ASC

CHARACTERISTICS CHART of SILICON ZENER or AVALANCHE DIODES

TYPE NO.	Zener or Avalanche Voltage Range MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Dynamic Impedance Z @ I_z (ohms)	(ma)	MAX. DISS. (mw)	TEMP. CO-EFFICIENT %/°C	MFR. {See code at start of chart}
AV8026	25.48	26.52	15	29	15	10000		ASC
AV8027	26.46	27.54	15	29	15	10000		ASC
AV8028	27.44	28.56	15	29	15	10000		ASC
AV8029	28.42	29.58	15	29	15	10000		ASC
AV8030	29.4	30.6	15	29	15	10000		ASC
AV8031	30.38	31.62	15	40	15	10000		ASC
AV8032	31.36	32.64	15	40	15	10000		ASC
AV8033	32.34	33.66	15	40	15	10000		ASC
AV8034	33.32	34.68	15	40	15	10000		ASC
AV8035	34.3	35.7	15	40	15	10000		ASC
AV8036	35.28	36.72	15	40	15	10000		ASC
AV8037	36.26	37.74	15	40	15	10000		ASC
AV8038	37.24	38.76	15	55	15	10000		ASC
AV8039	38.22	39.78	15	55	15	10000		ASC
AV8040	39.2	40.8	15	55	15	10000		ASC
AV8041	40.18	41.82	15	55	15	10000		ASC
AV8042	41.16	42.84	15	55	15	10000		ASC
AV8043	42.14	43.86	15	55	15	10000		ASC
AV8044	43.12	44.88	15	55	15	10000		ASC
AV8045	44.1	45.9	15	76	15	10000		ASC
AV8046	45.08	46.92	15	76	15	10000		ASC
AV8047	46.06	47.94	15	76	15	10000		ASC
AV8048	47.04	48.96	15	76	15	10000		ASC
AV8049	48.02	49.98	15	76	15	10000		ASC
AV8050	49	51	15	76	15	10000		ASC
AV8051	49.98	52.02	15	76	15	10000		ASC
AV8052	50.96	53.04	5.0	107	5.0	10000		ASC
AV8053	51.94	54.06	5.0	107	5.0	10000		ASC
AV8054	52.92	55.08	5.0	107	5.0	10000		ASC
AV8055	53.9	56.1	5.0	107	5.0	10000		ASC
AV8056	54.88	57.12	5.0	107	5.0	10000		ASC
AV8057	55.86	58.14	5.0	107	5.0	10000		ASC
AV8058	56.84	59.16	5.0	107	5.0	10000		ASC
AV8059	57.82	60.18	5.0	107	5.0	10000		ASC
AV8060	58.8	61.2	5.0	107	5.0	10000		ASC
AV8061	59.78	62.22	5.0	107	5.0	10000		ASC
AV8062	60.76	63.24	5.0	107	5.0	10000		ASC
AV8063	61.74	64.26	5.0	155	5.0	10000		ASC
AV8064	62.72	65.28	5.0	155	5.0	10000		ASC
AV8065	63.7	66.3	5.0	155	5.0	10000		ASC
AV8066	64.68	67.32	5.0	155	5.0	10000		ASC
AV8067	65.66	68.34	5.0	155	5.0	10000		ASC
AV8068	66.64	69.36	5.0	155	5.0	10000		ASC
AV8069	67.62	70.38	5.0	155	5.0	10000		ASC
AV8070	68.6	71.4	5.0	155	5.0	10000		ASC
AV8071	69.58	72.42	5.0	155	5.0	10000		ASC
AV8072	70.56	73.44	5.0	155	5.0	10000		ASC
AV8073	71.54	74.46	5.0	155	5.0	10000		ASC
AV8074	72.52	75.48	5.0	155	5.0	10000		ASC
AV8075	73.5	76.5	5.0	155	5.0	10000		ASC
AV8076	74.48	77.52	5.0	155	5.0	10000		ASC
AV8077	75.46	78.54	5.0	155	5.0	10000		ASC
AV8078	76.44	79.56	5.0	220	5.0	10000		ASC
AV8079	77.42	80.58	5.0	220	5.0	10000		ASC
AV8080	78.4	81.6	5.0	220	5.0	10000		ASC
AV8081	79.38	82.62	5.0	220	5.0	10000		ASC
AV8082	80.36	83.64	5.0	220	5.0	10000		ASC
AV8083	81.34	84.66	5.0	220	5.0	10000		ASC
AV8084	82.32	85.68	5.0	220	5.0	10000		ASC
AV8085	83.3	86.7	5.0	220	5.0	10000		ASC

UNDER TYPE NO.

☑ - Revised Specifications Δ - Also available with ±5 per cent tolerance

Ø - Double Anode Type † - Reference Amplifier

CHARACTERISTICS CHART of SILICON ZENER or AVALANCHE DIODES

TYPE NO.	Zener or Avalanche Voltage Range MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Dynamic Impedance Z @ I_z (ohms)	(ma)	MAX. DISS. (mw)	TEMP. CO-EFFICIENT %/°C	MFR. (See code at start of chart)
AV8086	84.28	87.72	5.0	220	5.0	10000		ASC
AV8087	85.26	88.74	5.0	220	5.0	10000		ASC
AV8088	86.24	89.76	5.0	220	5.0	10000		ASC
AV8089	87.22	90.78	5.0	220	5.0	10000		ASC
AV8090	88.2	91.8	5.0	220	5.0	10000		ASC
AV8091	89.18	92.82	5.0	330	5.0	10000		ASC
AV8092	90.16	93.84	5.0	330	5.0	10000		ASC
AV8093	91.14	94.86	5.0	330	5.0	10000		ASC
AV8094	92.12	95.88	5.0	330	5.0	10000		ASC
AV8095	93.1	96.9	5.0	330	5.0	10000		ASC
AV8096	94.08	97.92	5.0	330	5.0	10000		ASC
AV8097	95.06	98.94	5.0	330	5.0	10000		ASC
AV8098	96.04	99.96	5.0	330	5.0	10000		ASC
AV8099	97.02	100.98	5.0	330	5.0	10000		ASC
AV8100	98	102	5.0	330	5.0	10000		ASC
AV8105	102.9	107.1	5.0	330	5.0	10000		ASC
AV8110	107.8	112.2	5.0	330	5.0	10000		ASC
AV8115	112.7	117.3	5.0	500	5.0	10000		ASC
AV8120	117.6	122.4	5.0	500	5.0	10000		ASC
AV8125	122.5	127.5	5.0	500	5.0	10000		ASC
AV8130	127.4	132.6	5.0	500	5.0	10000		ASC
AV8135	132.3	137.7	5.0	500	5.0	10000		ASC
AV8140	137.2	142.8	5.0	800	5.0	10000		ASC
AV8145	142.1	147.9	5.0	800	5.0	10000		ASC
AV8150	147	153	5.0	800	5.0	10000		ASC
AV8155	151.9	158.1	5.0	800	5.0	10000		ASC
AV8160	156.8	163.2	5.0	800	5.0	10000		ASC
AV8165	161.7	168.3	5.0	800	5.0	10000		ASC
AV8170	166.6	173.4	5.0	1150	5.0	10000		ASC
AV8175	171.5	178.5	5.0	1150	5.0	10000		ASC
AV8180	176.4	183.6	5.0	1150	5.0	10000		ASC
AV8185	181.3	188.7	5.0	1150	5.0	10000		ASC
AV8190	186.2	193.8	5.0	1150	5.0	10000		ASC
AV8195	191.1	198.9	5.0	1150	5.0	10000		ASC
AV8200	196	204	5.0	1150	5.0	10000		ASC
SZ11C	10.42	11.58	20	25	20	1500	.07	GECB
SZ13C	12.32	13.68	20	40	20	1500	.075	GECB
SZ16C	15.16	16.84	20	60	20	1500	.08	GECB
SZ20C	18.95	21.05	20	90	20	1500	.083	GECB
SZ24C	22.74	25.26	20	120	20	1500	.085	GECB
SZ30C	28.42	31.58	20	160	20	1500	.097	GECB
SZ62A	5.87	6.52	20	12	20	1500	.03	GECB
SZ75A	7.1	7.9	20	12	20	1500	.045	GECB
SZ91A	8.62	9.58	20	18	20	1500	.06	GECB

UNDER TYPE NO.

☑ - Revised Specifications
Ø - Double Anode Type
* - Developmental Type
Δ - Also available with ±5 per cent tolerance
† - Reference Amplifier
# - Available with reverse polarity

SWITCHING DIODES

TYPE NO.	MAT	PIV (volts)	MAX. CONT. REV. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f (mA)	@ E_f (volts)	MAX. REVERSE CURRENT @ 25°C I_b (μa)	@ E_b (volts)	Recovery Characteristics TEST CONDITIONS Fwd. (ma)	Rev. I_f to E_b (volts)	$Z_{rec.}$ @ time (t) (K ohms)	(usec)	MFR. (See code at start of charts)
DW120	Si	100	100	400	1.0	.025	75	5.0	6.5	400	.004	DES
DW130	Si	100	100	50	1.0	.025	75	5.0	6.5	400	.004	DES
MD06	Si	60		20	1.0	.01	50	30	35	400	.30	GIC
MD08	Si	80		20	1.0	.01	70	5.0	40	100	.30	GIC
MD10	Si	100		20	1.0	.005	80	5.0	40	100	.30	GIC
UCI362	Si*	70	60	10	1.0	.025	20	10	6.0	6.0	.006	UCI

CHARACTERISTICS CHART of MISCELLANEOUS DIODE TYPES

TYPE NO.	CLASSIFICATION	DESCRIPTION	MFR.
1N3353	12	Backward Diode, VF-80mv at 1ma, Cd-4pf, LS-1nh	PHI
NSL33	4	CdS; .378 in. dia; 1.25 in. long; Spectral response that of human eye.	NSLC
PD300	M	3 diodes on single sliver of silicon; PIV-50V. min; If-10ma min. at 1V., tr-50nsec max.	DES
PD400	M	4 diodes on single sliver of silicon; PIV-50V. min; If-10ma min. at 1V., tr-50nsec max.	DES
PD500	M	5 diodes on single sliver of silicon; PIV-50V. min. If-10ma min. at 1V., tr-50nsec max.	DES

UNDER CLASSIFICATION

1 - Microwave Diodes
2 - Mixer or Detector Diodes
3 - Variable Capacitator Diodes
4 - Photodiodes
5 - Solar Cells
6 - Harmonic Generator Diodes
7 - 4-Layer Bistable Diodes
8 - Controlled Rectifier
9 - PNPN Switching Diode
10 - Tunnel Diode
11 - Photoconductive Cell
M - Other Miscellaneous Types

PREVIOUSLY REGISTERED NEWLY ANNOUNCED DIODES

ASSOCIATED TRANSISTORS LIMITED:
1N246C, 1N249C, 1N250C, 1N1195, 1N1196, 1N1197, 1N1198, 1N1199, 1N1200, 1N1202, 1N1203, 1N1204, 1N1205, 1N1206

COMMONS ELECTRONICS:
1N570, 1N1199, 1N1200, 1N1201, 1N1202, 1N1203, 1N1204, 1N1205, 1N1206

CONTINENTAL DEVICE:
1N903 thru 1N908, 1N903A thru 1N908A, 1N914, 1N914A, 1N916, 1N916A, 1N3064

INTERNATIONAL RECTIFIER:
1N429, 1N440 thru 1N443, 1N440B thru 1N443B, 1N456 thru 1N459, 1N456A thru 1N459A, 1N461 thru 1N470, 1N461A thru 1N470A, 1N465B thru 1N470B, 1N482 thru 1N488, 1N482A thru 1N488A, 1N482B thru 1N488B, 1N676 thru 1N684, 1N702 thru 1N716, 1N702A thru 1N716A, 1N746 thru 1N759, 1N746A thru 1N759A, 1N761 thru 1N766, 1N957 thru 1N973, 1N957A thru 1N973A, 1N957B thru 1N973B, 1N1313 thru 1N1320, 1N1313A thru 1N1320A, 1N1927 thru 1N1937, 1N1927A thru 1N1937A

MICROSEMICONDUCTOR:
1N897, 1N898, 1N899, 1N900, 1N901, 1N902, 1N3206, 1N3207

PACIFIC SEMICONDUCTORS:
1N851, 1N890, 1N891, 1N725 thru 1N745, 1N725A thru 1N745A, 1N905, 1N914, 1N914A, 1N916, 1N916A, 1N962 thru 1N992, 1N962A thru 1N992A, 1N962B thru 1N992B

RCA:
1N1199A, 1N1199RA, 1N1200A, 1N1200RA, 1N1202A thru 1N1206A, 1N1202RA thru 1N1206RA

UNITED COMPONENTS:
1N904, 1N914, 1N916

WESTINGHOUSE, U.S:
1N536 thru 1N540, 1N547, 1N560, 1N561, 1N1095, 1N1096

ANNOUNCING :

SEMICONDUCTOR

- CONTAINS COMPLETE CHARACTERISTICS OF MORE THAN 2,800 TYPES.
- TWO SETS OF CHARTS PROVIDE:

  1) NUMERICAL TABULATION

  2) LISTINGS IN ORDER OF MOST IMPORTANT DESIGN PARAMETERS.*
- CHARTS PREPARED BY THE NATIONAL BUREAU OF STANDARDS.

SEMICONDUCTOR
Diode Source Book
FEATURING.
• SWITCHING DIODES. by G. A. Frechette
• VARACTOR DIODES. by Seymour Cohen
• MICROWAVE MIXER and DETECTOR DIODES. by Eugene J. Feldman
• ZENER DIODES–DESIGN CONSIDERATIONS and APPLICATIONS. by Charles A. Signor
• PHOTO DIODES. by Don Abel
• TUNNEL DIODES. General Electric Company
• CIRCUIT DESIGN and APPLICATIONS of HIGH POWER SILICON RECTIFIERS. by N. A. Forbes
SAMUEL L. MARSHALL EDITOR
Charts Compiled by National Bureau of Standards

$2.50

IODE SOURCE BOOK

- **AN ADDITIONAL CHART LISTING AVAILABILITY OF DEVICES FROM VARIOUS MANUFACTURERS.**
- **CHARTS ARE NOTEWORTHY FOR THEIR EASE OF USE AND COMPLETENESS OF PARAMETERS.**
- **PACKAGING INFORMATION INCLUDED.**

***Separate charts are provided for each diode type. These charts are arranged in an ascending order of the numerical values of the most important parameter of the device. This permits a rapid selection of a specific type to meet the needs of the design engineer.**

ORDER YOUR COPY NOW!

Price only **$2.50** postage paid in the U.S.A. and possessions.

SEMICONDUCTOR PRODUCTS
300 W. 43rd St., New York 36, N.Y.

SIRS: My check (money order) for $____ is enclosed.
Please send Semiconductor Diode Source Book to:

NAME _____

STREET ADDRESS _____

CITY _____ ZONE ____ STATE _____

N.Y. City residents add 3 % Sales Tax.

Publication Date on or about *AUGUST 31st 1961*

Market News

(continued from page 18)

Dow Corning is now in production of polycrystalline silicon, in several forms, and float-zoned single crystal silicon at their Hyper-Pure Silicon Division located in Hemlock, Michigan. This division occupies seven buildings totaling 37,000 square feet of floor space. These facilities, representing an investment of more than $2 million, have a capacity of 25,000 pounds of high purity silicon a year.

Prices

Sperry Semiconductor Division has announced prices on six of their silicon choppers.

	1-99	100-999
2N1917	$ 9.75	$7.50
2N1918	7.80	6.00
2N1919	12.35	9.50
2N1920	8.77	6.75
2N1921	5.20	4.00
2N1922	6.50	5.00

Cominco Products, Inc., Spokane, Washington has announced a price reduction of up to 20% on quantity orders of 50 and 100 gram ampoules of Cominco 69 Grade Arsenic. This material, approaching 99.9999% pure is made particularly for the preparation of gallium arsenide.

National Semiconductor, Danbury, Conn., has developed a series of silicon n-p-n epitaxial high speed switching transistors. This compact TO-18 series, NS-381, NS-382, NS-383 and NS-384 features faster switching speeds, high breakdown voltages, low saturation voltages, and low output capacities. Prices range from $20.90 to $22.90 in 1-99 quantities; and from $13.90 to $15.20 in 100-999 quantities.

Semi-Elements, Inc. announces pilot plant production of lead telluride. This material is available both in single crystal form and polycrystalline form, both N type and P type material is available. Prices of this material, in small quantities is $.50 per gram in kilogram lots or less. In lots of a kilogram or more, the prices will be quoted special.

A new line of highly stable, low temperature coefficient Zener reference units has been announced by Pacific Semiconductors, Inc. Type numbers, temperature coefficients and 100 to 999 prices are as follows: PS1511 (.01%) $7.65; PS1512 (.008%) $8.95; PS1513 (.006%) $10.65; PS1514 (.004%) $13.20; PS1515 (.002%) $16.15; PS1516 (.001%) $23.80; and PS1517 (.0005%) $34.00. PSI also announced the addition of types 1N1737 thru 1N1742 to its line of low temperature coefficient Zener reference diodes. Other types added to their Zener diode line include high voltage series 1N962B thru 1N992B and 1N725 thru 1N745.

Distribution

The Bendix Corp., now has its semiconductors available from stock in quantities up to 999 from fifteen distributors located throughout the nation.

Alpha Metals, Inc., Jersey City, N. J., has opened a sales and manufacturing division in London, England. The new leased plant will occupy 2,000 square feet. This European division is being set up to supply semiconductor device manufacturers in the United Kingdom and on the Continent with the high purity microminiature metal forms used in transistors, diodes and other semiconductor devices.

Trak Electronics Company, Inc., of Wilton, Connecticut has recently appointed Cain and Company as midwestern sales representatives for all their product departments. This arrangement will include the area from the Great Lakes to the Gulf of Mexico and from the Appalachians to the Rockies.

General Electric's Semiconductor Products Department, Syracuse, N. Y., has opened two new sales offices and added six new district sales managers in its eight state northeastern sales region. The new sales offices have been established in Hartford, Connecticut and in Garden City, Long Island. Other sales offices in the region are located in Syracuse, New York, Clifton, N. J. and Newtonville, Mass.

Westmore, Inc., Fanwood, New Jersey, announces the appointment of Anderson Sales Co., Boston, Massachusetts, as their exclusive representative in the New England area for their line of electron tube and transistor testing equipment and regulated power supplies.

Western Transistor Corporation, Gardena, California, manufacturers of WesTran p-n-p silicon alloy transistors has announced the appointment of Minthorne International Company, Inc., New York 4, New York to handle their international business, with the exception of Canada.

Electronic Metals and Alloys, Inc., Watertown, Mass. has named R. H. Matthews and Associates, Inglewood, Calif., to provide sales representation in California and Arizona.

Fansteel Metallurgical Corp., North Chicago, Ill., has launched a program to increase the number of franchised distributors of its silicon and selenium rectifiers and tantalum capacitors. The plan is to add distributors in 12 new areas where the firm has sales engineer offices through a recently formed "master distributor." NEWS Electronics Corp., of Culver City, Calif., and Clifton, N. J.

Fairchild Semiconductor, Inc., has established a distribution program in which manufacturer's representatives will buy and maintain inventories of its semiconductor line. Under this system seven representatives throughout the country will operate as "stocking reps" and will receive price protection with industrial distributors.

Dickson Electronics Corporation, has named three new distributors and one new manufacturer's representative. The new distributors are Finn Electronics, Los Angeles; Stack Industrial Electronics, Inc., Binghamton, N. Y.; and Texzotic Engineering Sales & Service, Dallas, Texas. The new representative is the Robert L. Hanna Company, Franklin Park, Illinois, who will represent the Dickson company in Illinois, Wisconsin, Minnesota and Iowa.

The Birtcher Corporation's Industrial Division has announced the appointment of the following distributors for its line of tube, transistor and component retention and cooling devices: Interstate Industrial Electronics, Inc., St. Louis for the State of Missouri; S. Sterling Company of Detroit for the State of Michigan, and Capital Radio Wholesalers, Inc., of Washington, D. C. for that area.

Northeast Electronics Distributors, Inc., Hartford, Connecticut, has just been appointed a stocking distributor of Cambion(R) electronic components, according to an announcement of Cambridge Thermionic Corporation, Cambridge, Mass.

Financial

Sperry Rand Corp., showed a decline of 25% in earnings for the fiscal year ending March 31 despite a slight gain in sales. Net profit for the year totaled $27,815,655 equal to 95¢ a share compared with $37,235,823 or $1.30 a share, earned the previous year. Sales of products and services amounted to $1,176,999,343 against $1,173,050,913 in the prior fiscal year.

Allied Radio Corp., Chicago has reported a 16.3% sales increase for the nine-month period ending April 30. Earnings, however, were 12.2% under the preceding year's nine-month period. Net profit for this period was $824,173 equal to 78¢ a share compared with $938,409 or 90¢ a share for the same period a year ago. Sales rose to $30,875,335 from $26,543,076.

Expansion

Burndy Corporation, Norwalk, Connecticut and Glass-Tite Industries, Inc., Providence, R. I. have just announced an agreement by which Burndy will acquire a 50% interest in Escon, Inc., subsidiary of Glass-Tite.

(Continued on page 58)

New Products

Lead Telluride

The manufacture of a thermoelectric generator material, lead telluride was announced by Alloys Unlimited Chemicals. It is used as elements in generators which supply the auxiliary power for space satellites, buoys, and other devices where power must be supplied independent of external sources. Efficiencies of 6% or more have been delivered by this material. The material is square, providing for maximum concentration within a minimum area, but can also be fabricated in other shapes.

Circle 168 on Reader Service Card

Midget Heat Sink

Hunter Tools is now producing a smaller, lightweight, Heat Sink. It is only 1¼" long and has slimmer points to get into confined areas. These new heat sinks are made of Berylco 10 because of its high

thermo-conductivity and good spring characteristics. The handles are covered with plastic to keep finger area cool and comfortable. To order specify stock #51G.

Circle 151 on Reader Service Card

Microcircuit Border

K&S Model 601M Multi-Dice Bonder is designed and manufactured by Kulicke and Soffa Manufacturing Company, Inc., specifically for work with header-mounted circuits. It is capable of handling (in one continuous operation) semiconductor dice, gold foil and a variety of micromodules. It positions these microcomponents on the header to an exacting accuracy of 10 to 15 millionths of an inch and bonds them quickly and effectively.

Circle 171 on Reader Service Card

"Pancake" Drift Field Transistor

Latest addition to the Sylvania "Pancake" transistor line is a miniaturized version of the 2N1225 designed for amplifier applications in the VHF frequency spectrum. The new "Pancake" unit, one-tenth the size and weight of its TO-33 counterpart, offers substantially improved power dissipation and meets environmental tests in accordance with MIL-S-19500B. Designated Type 2N1699, it has a collector to base voltage of −40 volts, an emitter to base voltage of −0.5 volts, and a power dissipation of 100 mw in free air.

Circle 110 on Reader Service Card

Transistor Test Equipment

Fairchild Semiconductor Corporation has entered the field of transistor test instrumentation and now has a number of go no-go and absolute readout transistor testers, available either for sale or lease, and will be built to customer specifications. Available on order is Type 4, an automatic multi-parameter tester featuring automatic sorting and classification. Also being produced is: a Data Logger, an automatic Lower Limiting Voltage tester, a Low Leakage-current tester, a wide range d-c pulse current gain tester, and a variety of other units.

Circle 130 on Reader Service Card

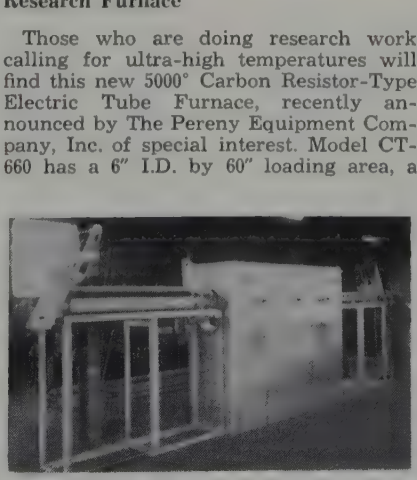
Silicon Power Transistors

Tyco Semiconductor Corporation announced the availability of diffused silicon power transistors with operating temperatures to 200° C. The new devices feature high current gain (HFE—45 minimum @ IC = 1 ampere @ 15 volts), collector voltage ratings to 100 volts, and beta frequency products in the 50 mc range. All devices are available in a variety of all welded package configurations including stud and flange mount types.

Circle 117 on Reader Service Card

Research Furnace

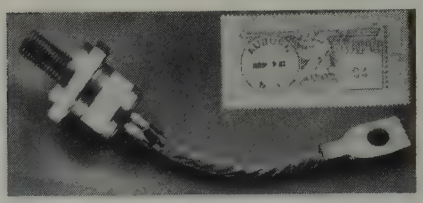
Those who are doing research work calling for ultra-high temperatures will find this new 5000° Carbon Resistor-Type Electric Tube Furnace, recently announced by The Pereny Equipment Company, Inc. of special interest. Model CT-660 has a 6" I.D. by 60" loading area, a full heated length of 60" and an even temperature zone of 36." It is capable of reaching the full 5000° temperature in approximately two hours. This furnace is equipped with a Saturable Core Reactor Power Pack capable of supplying power (440/60/1) continuously variable from 1 to 100% of connected load.



Circle 154 on Reader Service Card

High Voltage Silicon Rectifiers

A commercial series of high current silicon rectifiers with a PRV rating up to 1,000 volts is offered by the General Electric Company. Availability of the unit

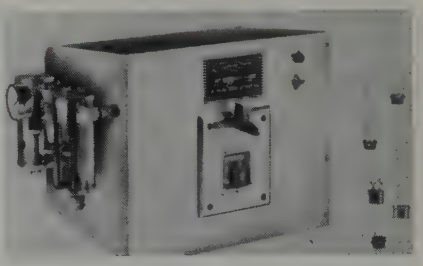


with a transient voltage rating of 1300 volts will offer designers the opportunity to use one cell across a 440-volt line instead of two or more cells. The new rectifier can be used to replace existing lower voltage silicon rectifier cells in the 50 to 100 ampere range.

Circle 159 on Reader Service Card

Automatic Transistor Machine

A new machine that automatically straightens, cuts, and notches more than 1000 transistor leads an hour, has been announced by Design Tool Co., Division of Federal Manufacturing & Engineering Corp. The machine is available in two versions, a transistor straightener, Model



AL3S, and a cutter-notcher, Model AL3NS. Both machines are designed for bench mounting, power requirements are 110 volts, 60 cycle and 80 PSI of compressed air.

Circle 157 on Reader Service Card

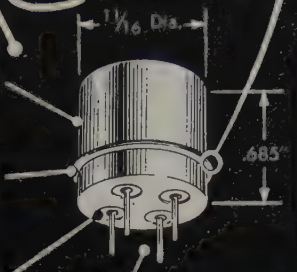
Automatic Diode Recovery Test Set

Automatic readout of diode recovery measurements can be made accurately and rapidly with the new Model 410 Automatic Diode Recovery Test Set announced by Lumatron Electronics, Inc. Automatically measures the reverse recovery times of diodes down to less than 1 ns. The test result is available as either a front panel meter reading, or an analog voltage proportional to the recovery time, permitting operation by inexperienced personnel, or the installation of the instrument on fully automatic production lines. For laboratory and evaluation work, a monitor output is available.

Circle 169 on Reader Service Card

(Continued on page 60)

NEW KOLDWELD* SEALED HERMETIC ENCLOSURE from SAC



Aluminum cap and base —clean—light in weight —non-magnetic

Patented KOLDWELD* sealing for the ultimate in tight, strong ultra clean closure.

SAC ceramo-glass aluminum seal, vacuum tight, physically strong.

Part No. 110-1
Other heights available

Fits standard 7 pin miniature socket—up to 7 pins available.

Sealing presses, engineering service, rights to process enclosures all available from one source.

Scully-Anthony Corp. has pioneeded KOLDWELD* (Reg. trade mark) sealed enclosures.

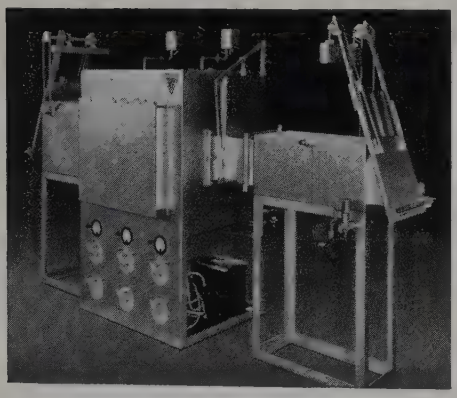
For further information regarding enclosures, write Dept. SP1

SCULLY-ANTHONY CORPORATION.... a division of SCULLY JONES

4707 WILLOW SPRINGS ROAD • LA GRANGE, ILLINOIS

Circle No. 27 on Reader Service Card

For Critical Heat Treating Processes



muffle type hydrogen-reduction three zone

PERECO
STRAIGHT-LINE FURNACE

This 3-zone, straight-line Pereco Hydrogen-Reduction Furnace is especially designed to perform critical heat treating processes, such as reducing tungsten oxide powder to pure tungsten metal. It has counter-balanced sliding plate doors and solenoid-operated flame curtains at each opening. Interior blast-gates, manually operated from the outside, separate the hot zone from both the entrance and exit areas. Other features, as well as possible design modifications, make this type of unit well worth investigating if you have critical heat treating work to do. Write us.

Standard or special furnaces and kilns for temperatures from 450° F to 5000° F.

PERENY EQUIPMENT Co., Inc.

Dept. M, 893 Chambers Rd., Columbus 12, O.

Circle No. 28 on Reader Service Card

Market News

(from page 56)

Nuclear Corporation of America has recently acquired U. S. Semiconductor Products, Inc.

Loral Electronics Corporation, New York, and Accurate Specialties Company, Inc., have jointly announced that the plan for the acquisition of the latter by Loral has been terminated by mutual agreement of both parties.

Foxboro Co., Foxboro, Mass. has opened its 40,000 square foot assembly plant costing about $70,000. Production of their solid state line has been transferred to the new plant.

Texas Instruments, Inc., Semiconductor and Components division has been split into two new divisions—the Transistor division and the Components division.

The semiconductor engineering and manufacturing group of Bendix Corp., Red Bank, N. J. has been established as a separate division. The division will be located at Holmdel, N. J.

Westinghouse Electric Corp., has formed a new department for the development, manufacture and marketing of molecular electronics functional blocks. These units perform circuitry functions previously accomplished by separate components such as transistors, diodes, resistors and capacitors.

Raytheon has formally opened their new 116,500-square-foot, $2¼ million building in Lewiston, Maine. The plant, now employing 900 is manufacturing n-p-n and p-n-p alloy junction germanium transistors in the conventional TO-5 size and the newer subminiature size package. Gold-bonded germanium diodes are also in production. Mesa type transistors for high speed switching applications will soon go into production.

Arco Electronics, Inc., has established a new headquarters plant in a 46,000 square foot facility in the Lake Success Business and Professional Park, Great Neck, N. Y. Arco is an exclusive sales and marketing agency for manufacturers of electronic products, and is itself a manufacturer of complementary components.

National Ultrasonic Corp. moved to larger and more manufacturing facilities in Nutley, New Jersey. This new plant will provide approximately 15,000 square feet of manufacturing and 3,000 square feet of office and engineering area.

Bell Electronic Corp., Los Angeles, Calif., an electronics warehousing and distribution firm will start assembly soon of its own line of semiconductor products, through a newly-organized, wholly-owned subsidiary called Bell Electronic Manufacturing Corp., which will cover qualification, marking, packaging and marketing of transistors and other semiconductors. The new subsidiary's products will be directed principally at commercial and industrial markets for use in communications, computers, and other applications requiring high precision devices.

New Firms

Semi-Onics, Inc., Lowell, Mass., has been established to do research, development and manufacture of high-powered devices, with emphasis on silicon and germanium transistors. The firm also will work on high frequency silicon transistors. Semi-Onics has been capitalized at more than $500,000 and for the present will operate on a 13,000 square foot leased space.

American Micro Devices, Inc., has been established to develop and manufacture semiconductor devices for the military and commercial computer markets. The new firm has filed articles of incorporation with the State of Minnesota and will carry on its operations in Phoenix.

Advanced Micro-Electronics, Inc., Cranston, R. I., has been formed to produce transistors and diodes.

Beta Instruments Corp., has been formed in Dallas, Tex. as a subsidiary of Cadre Industries Corp., Endicott, N. Y. The new firm will develop and market a line of transistorized quality control and test instruments for semiconductor component manufacturers as well as some consumer electric products.

The organization of a new subsidiary company, United Components, Inc. of New England, in Worcester, Mass., has been announced by United Components, Inc., Orange, N. J. The new company, housed in a 30,000 square foot facility, will expand the parent firm's lines in the semiconductor field, laying particular emphasis on the manufacture of controlled silicon rectifiers.

FOR STAMPINGS *CALL J&H*

Semi-conductor precision metal stampings and deep-drawn parts. Made to close tolerance at low cost. Fast service. Write or phone for prices and free copy of Bulletin 82.

An affiliate of Superior Tube Co.

J&H

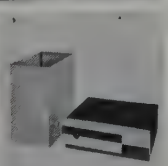
JOHNSON & HOFFMAN

MANUFACTURING CORPORATION

31 East 2nd Street • Mineola, New York • Pioneer 2-3333

Circle No. 29 on Reader Service Card

ACOUSTICA ULTRASONICS MAY DO YOUR CLEANING JOB IN 1/35 THE TIME!



Incomparably fast and thorough cleaning is yours with Acoustica ultrasonic cleaning systems. One major connector manufacturer, for example, has reduced the job of cleaning 21,000 components from 416 man-hours to 12! Another company cleans 600-circuit slip rings in a 15-second ultrasonic dip. You, too, can save time, money and rejects with an Acoustica system. Write for *free* application data sheets.

COMPLETE LINE OF VACUUM TUBE AND TRANSISTORIZED MODELS AVAILABLE FOR IMMEDIATE DELIVERY. WE INVITE YOUR REQUIREMENTS FOR CUSTOM-DESIGNED UNITS.

acoustica

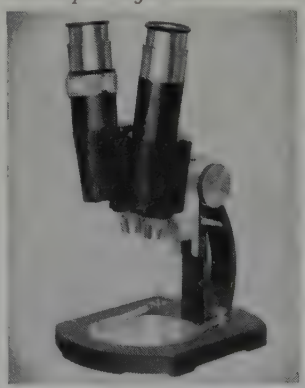
GENERAL ULTRASONICS DIVISION
10400 Aviation Boulevard, Los Angeles 45, Calif.
463 Old Country Road, Westbury, L.I., N.Y.

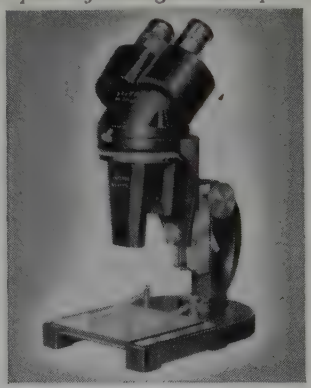
COVERED BY ONE OR MORE OF THE FOLLOWING U.S. PATENTS: 2,873,392; 2,947,889; 2,956,538; 2,956,789 AND BY FOREIGN PATENTS. OTHER U.S. AND FOREIGN PATENTS PENDING.

Circle No. 30 on Reader Service Card

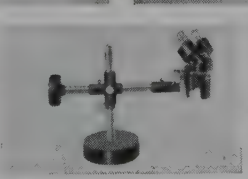
NEW UNITRON stereo microscopes .....as low as $110

Both models offer . . . sharp clear erect image • large depth of focus • wide field • long working distance • interpupillary and diopter adjustments • rack and pinion focusing • coated optics





MSL — a precision, budget priced instrument. Vertical binocular body. Choice of single magnification from 5X to 45X. Extra eyepieces for additional powers, $19.50 per pair. **$110**



ACCESSORY STAND — For use with binocular head and focusing mechanism of either Model MSL or MSHL. Price (stand only), $75.

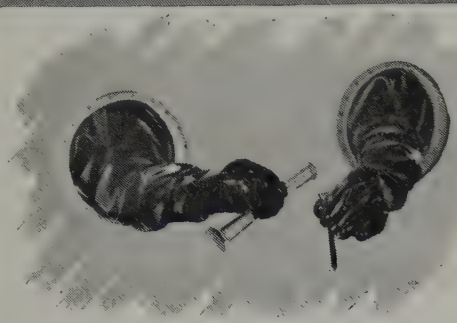
MSHL — a versatile general purpose instrument with a wide range of magnifications. Inclined binocular body, revolving nosepiece for rapid interchange of objectives. Model MSHL-1 with objectives: 1X, 2X, 3X; eyepieces: 8X, 12X, 15X; magnification range: 8X-45X. Other magnification ranges available. **$267**

AVAILABLE FOR FREE 10-DAY TRIAL . . . WRITE FOR FREE CATALOG 47-S

UNITRON INSTRUMENT COMPANY • MICROSCOPE SALES DIV.
66 NEEDHAM ST., NEWTON HIGHLANDS 61, MASS.

Circle No. 54 on Reader Service Card

FOR DEPENDABLE PROTECTION
IN CRITICAL OPERATIONS



CHARCO
DRY BOX
GLOVES

PREMIUM QUALITY
MILLED NEOPRENE

FLEXIBLE, FINGER SENSITIVE AND COMFORTABLE

EACH DRY BOX GLOVE IS HIGH VOLTAGE TESTED

CHARCO NEO-SOL ®

PREMIUM QUALITY, ALL MILLED NEOPRENE. THESE GLOVES ARE OIL, CHEMICAL AND OZONE RESISTANT. THEY CONFORM TO REQUIREMENTS OF ARGONNE NATIONAL LABORATORY SPECIFICATIONS PF-1-b-(Rev. 6).

® CHARCO RAD-BAR

SEAMLESS, LEAD-LOADED, MILLED NEOPRENE ARE OF A DENSITY OF 3.95 GRAMS PER CUBIC CENTIMETER. UNDER ACTUAL TESTS THESE GLOVES HAVE BEEN PROVEN TO SHIELD OUT SOFT GAMMA RAYS MORE THAN 85%.

WRITE FOR BROCHURE AND TECHNICAL DATA

Our Research and Testing Laboratories Welcome The Opportunity To Help Solve Your Problems.

CHARLESTON RUBBER COMPANY

53 STARK INDUSTRIAL PARK — CHARLESTON, SOUTH CAROLINA

Circle No. 31 on Reader Service Card

OUR CLIENTS

are seeking to purchase firms in all segments of the electronic industry. If your company is interested in negotiating toward that end, contact us immediately. All correspondence kept in strictest confidence.

ELINEX

SEMICONDUCTOR PRODUCTS
Box 98 SCP
300 West 43rd St.,
New York 36, N. Y.

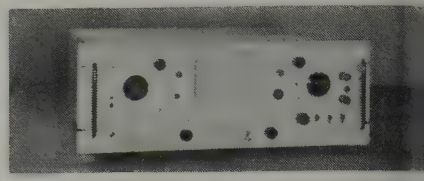
Circle No. 98 on Reader Service Card

New Products

(from page 57)

Oscilloscope

A rack-mount oscilloscope that accepts a wide range of plug-in units in both channels, Tektronix Type RM561 permits



almost any type and degree of performance demanded for a particular application. Characteristics of the Indicator Unit include: 5" rectangular crt, 3.5 kv accelerating potential, 8 x 10 centimeter viewing area, z-axis input, amplitude calibrator, regulated d-c heater voltage, and regulated d-c supply that operates between 105 to 125 volts or 210 to 250 volts, 50 to 800 cycles to provide 90 watts of power for the plug-in units.

Circle 153 on Reader Service Card

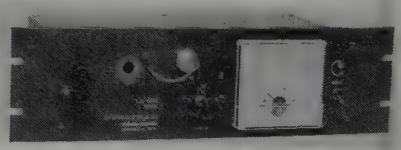
Bar Solder

A new bar solder that has been effective in cutting printed circuit joint rejects from 8 in 400 to 1 in 5,000 is now available from Alpha Metals, Inc. Photomicrographs indicate that it is significantly freer of oxide-forming elements and as a result, cuts dross, increases bath life, reduces inherent inclusions, improves wetting and produces brighter joints. "Alpha AAA (R) Solder" is said to provide more finished units per pound and is available in most of the common tin-lead alloys.

Circle 150 on Reader Service Card

Test Set

Dynatran announces the latest addition to its line of transistor test instruments, the Model 1824 r_b C_c Test Set. This direct reading, easy to use instrument is well

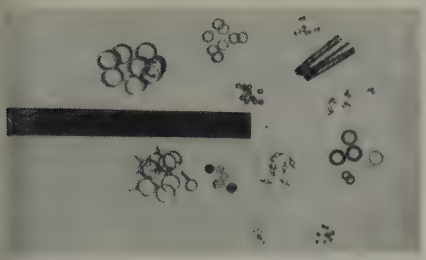


suited for laboratory, production testing and incoming inspection of mesa, surface barrier and drift transistors. Range of r_b' C_c: 0-30, 0-100 and 0-300 uusec. Accuracy: 5%. The instrument includes a built-in test socket which accommodates both long and short lead transistors.

Circle 163 on Reader Service Card

Ultra-Thin Pellets And Washers

A new stamping process, designed especially to meet the requirements of the Mesa transistor and epitaxial semiconductor devices has just been announced by Semi-Alloys, Inc. The new process produces extremely flat, intricately shaped pellets and washers from semiconductor materials such as indium, gold, lead, tin, aluminum, and a wide range of alloys



to meet design specifications. Stampings, with thicknesses ranging as low as 250 millionths of an inch are possible, and degree of flatness can be held to microscopic levels.

Circle 164 on Reader Service Card

High Vacuum Pumping Systems

Two, four and six inch systems evacuate Tri Metal's standard high vacuum ovens. A base plate and bell jar can be mounted on the flange for high vacuum evaporation or research studies. This completely packaged high vacuum pumping system includes a diffusion pump, liquid nitrogen trap, mechanical pump, pneumatically operating high vacuum valves, push button operation, sequence control and is electrically interlocked to prevent operational errors.

Circle 160 on Reader Service Card

Semiconductor Material Slicer

Reid Brothers Company, Inc., has announced that the new Model 612 Slicer eliminates machine variables in slicing silicon, germanium or many other types of semiconductor material. The Slicer has a cross-feed index within plus or minus .0001. The application of the Post Electronic Counter controls the repeatability accuracy of the cross-feed increment. Features include variable speeds, faster "slug set-up" and easy to read dial settings.

Circle 158 on Reader Service Card

Switching Power Supply

For use in simulated life testing of a group of diodes, Aerotronic Associates announces its Model 293B Relay Type Switching Power Supply. It is rated to

supply maximum of 50 amperes average forward current at 12 volts and peak inverse voltages up to 1400 volts. Both the forward and the reverse outputs are metered and may be adjusted by powerstats. The input is 115/220 v, 60~ AC at meters, etc.)

Circle 167 on Reader Service Card

Silicon Planar Transistors

General Instrument Semiconductor Division announces development of a series

INSTRUMENTS TO DETERMINE:

- LIFETIME
- HALL VOLTAGE
- RESISTIVITY
- THERMOELECTRIC VOLTAGE
- P & N JUNCTIONS
- TYPE TESTING OF SEMICONDUCTORS

IMPROVED LIFETIME MEASURING EQUIPMENT — MODEL LM-2A

IMPROVED Minority Carrier Lifetime Measuring Equipment (LM-2A illustrated)

IMPROVED Thermo Electric Probe, Model TE-1A

NEW Thermo Potentiometer — measures thermoelectric voltage

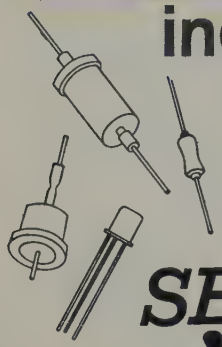
NEW Microwave Resistivity Probe — measures Resistivity without contact problems

NEW Alternating Current Magnet Hall coefficient measuring equipment

WRITE TODAY FOR COMPLETE INFORMATION

Electro IMPULSE LABORATORY INC. | 208 RIVER ST. • RED BANK, N.J. Phone: SHadyside 1-0404

Circle No. 61 on Reader Service Card



increase your yield with SECON SEMICONDUCTOR Wire

precision engineered to the special requirements of the semiconductor industry

SECON SEMICONDUCTOR WIRE IS TOPS IN THESE VITAL AREAS...

- purity
- homogeneity
- reliability
- repeatability

For more information, or for a solution to your specific wire problems, write today to SECON METALS CORPORATION, Seven Intervale Street, White Plains, N.Y. (WHite Plains 9-4757).

SECON METALS

RELIABLE WIRE FOR THE HEART OF YOUR COMPONENT

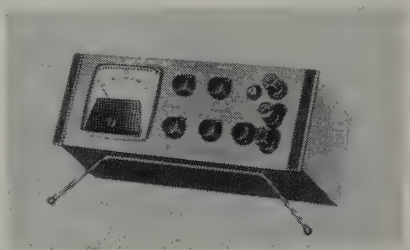
Circle No. 33 on Reader Service Card

of silicon n-p-n planar switching transistors, which are available in production quantities. The series utilizes the latest techniques in planar diffusion and features the high reliability 2N708. Other standard types available are the 2N706, 2N706A, 2N706B and 2N707. All units are hermetically sealed in a standard TO-5 metal case with glass insulated header and are highly resistant to extreme atmospheric conditions.

Circle 152 on Reader Service Card

Tunnel Diode Power Source

Electronic Research Associates, Inc., announces a new Tunnel Diode Power Source, Model TD6M, which is intended for both laboratory and factory powering

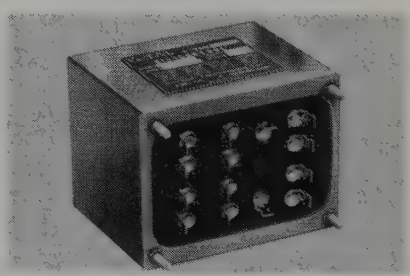


of tunnel diodes or similar devices. The unit provides an adjustable output over the range 0-6 VDC. A vernier control knob is also provided which permits vernier adjustment at any voltage output over a ± 0.5 volt range. The current rating is 0.100 ma. Regulation corresponds to 0.05% or 2 mv for full input voltage variations of 105-125 VAC, 60-400 cps and 0-100% load change.

Circle 156 on Reader Service Card

Packaged Gate Drive

A new packaged gate drive for silicon-controlled rectifiers, the "Flat Top" Silicontrol, is available from VecTrol Engineering, Inc. The leading edge of the pulse advances linearly in relation to



control signal, and with constant amplitude, for a full 180° phase shift, and is then locked in phase at 180° to give maximum SCR output even with excessive control signal. Fast pulse rise time of 1 to 5 microseconds is followed by a substantially constant amplitude wide rectangular configuration extending for approximately 90°; this ensures positive firing even under the most adverse dynamic load conditions.

Circle 162 on Reader Service Card

Laboratory Furniture

An extensive new line of laboratory furniture is now available from Will Corporation. Functionally designed for installation in any laboratory, even those having the strictest space requirements, WILLAB includes all basic furniture

PRECISION GLASS

T. H. GARNER COMPANY

MANUFACTURED TO YOUR SPECIFICATIONS

One of a kind, or millions of parts ... you get the closest tolerances from GARNER—tolerances which have led the field in the redrawn glass industry since 1953.

Large stocks of many different glass types and sizes—including the unusual. Available for immediate redraw.

Customer minded—We constantly upgrade equipment and techniques to keep ahead of your needs. You'll find us especially helpful on difficult requirements.

On-time deliveries—GARNER is geared for volume production to tight specifications—on a day-to-day basis. You get the parts you need ... when you need them.

Send for complete data.

T. H. GARNER COMPANY

177 S. Indian Hill Blvd.
Claremont, Calif. • NAtional 6-3526

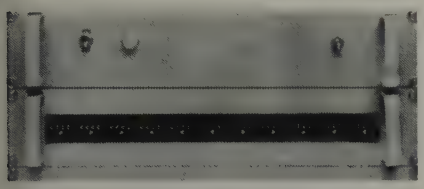
Circle No. 34 on Reader Service Card

units: cabinets, counter tops, tables, desks, lockers, fume hoods, sinks, carts, chairs, etc. Units are all dimensionally standardized and may be re-arranged at any time to suit changing laboratory requirements. Individual components such as sliding drawers may be replaced by open cabinets and vice versa.

Circle 155 on Reader Service Card

Transistor Fault Counters

Optimized Devices, Inc., Transistor Fault Counters operate in various modes to display fault count distribution for transistors under test. Model C-10 will



display the total number of transistors tested on othe indicator labeled "Starts." Indicators 1-10 will display the number of transistors which do not pass tests 1-10 respectively. These tests may be standard transistor measurements. Model C-2 will display the total number of transistors tested and the total number which pass all tests.

Circle 161 on Reader Service Card

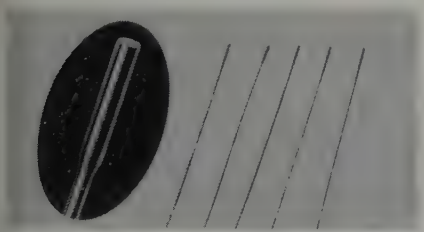
Silicon Rectifiers

Fifty three diodes have been added to Raytheon Company's line of diffused-junction silicon rectifiers. All welded and hermetically-sealed in a metal and glass case, the high-temperature, medium-current rectifiers are designed for use where high inverse voltages, high forward conductance, very low leakage current, and extremely high rectification efficiency are required. Operating ambient temperature range is −65 to +175° C.

Circle 172 on Reader Service Card

One-Piece Lead Wires

Newly developed by Art Wire And Stamping Company, are one-piece, necked-down lead wires for glass sealing applications. Eliminating the welded



joint, these new type leads are offered in most glass sealing alloys. Approximately 3" long, they are available in diameters from .020" to .050", which may be necked down by as much as 50% of the original wire size.

Circle 165 on Reader Service Card

Silicon Diodes

Five new "universal" silicon diodes PS5300-PS5304, were announced by Pa-

high speed automatic dice gaging and sorting for the semi-conductor industry

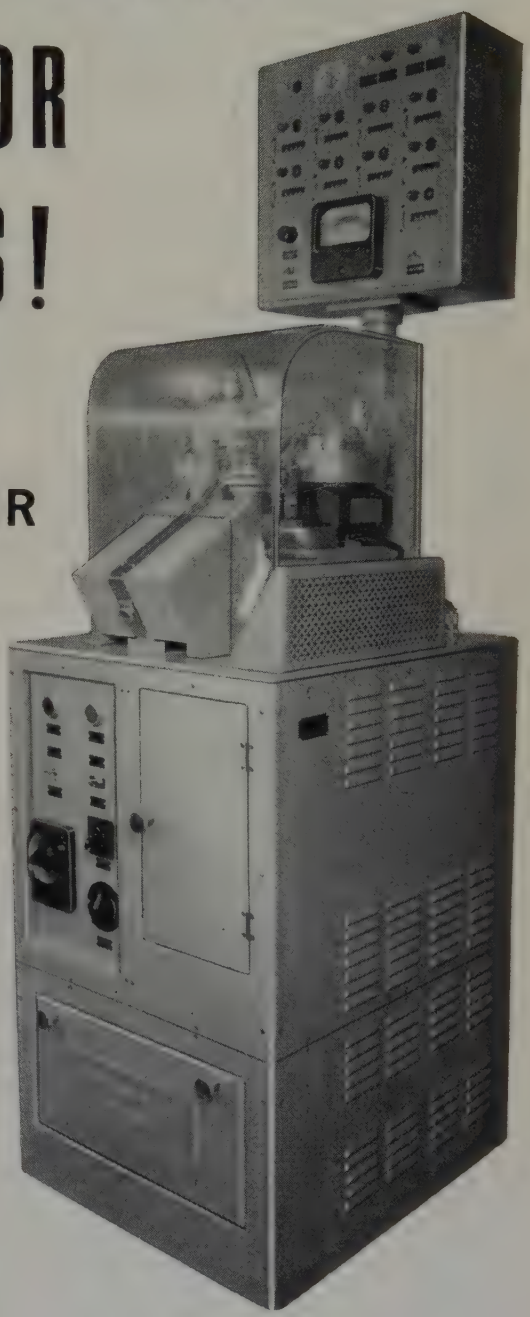
80% SAVINGS IN LABOR COSTS!

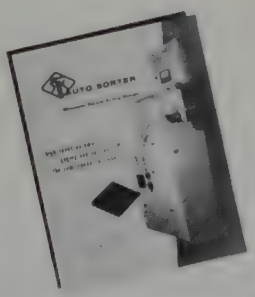
TSK AUTO-SORTER

Let a Techni-Rite sales engineer show you how to reduce **your** dice/wafer sorting costs by **eliminating completely up to 4 out of 5 inspection and sorting personnel.**

The new TSK Auto-Sorter is a dependable, high-speed production unit which automatically gages and sorts germanium or silicon dice into various categories . . . faster, and with far greater accuracy, than human hands. One transistor manufacturer reduced his work force from 30 to 6 virtually overnight!

Nearly 200 TSK Auto-Sorters are now in constant service. Factory-trained installation and service experts . . . and a complete inventory of replacement parts . . . are on hand at all times.





Phone, Wire or Write for Illustrated Folder

techni-rite ELECTRONICS INCORPORATED

67 Centerville Road • Warwick, Rhode Island • REgent 7-2000

Circle No. 35 on Reader Service Card

WILLIAM C. DIMAN,

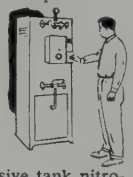
Furnace Div. Mgr. explains . . .

WHY ELECTRONICS TURN TO HAYES for crystal growing, etc.

Extremely Close Process Control is vital in manufacturing semi-conductors and other electronic parts. Without this control, costs and scrap rates go up, product performance becomes unpredictable, and product life is drastically reduced. *The Trend Is To Hayes*—More and more electronic firms are looking to Hayes for consulting assistance and for equipment to solve complex and exacting heat treat jobs. Here are some "for instances" of the advanced equipment Hayes is offering:

HAYES BA-19D DIFFUSION FURNACE Highly precise unit assures even diffusion on silicon or germanium wafers. Extremely critical temp. control (reactor type). Uniform "flat" zone in depositing chamber totally free from temp. "ripples". Engineered atmospheres and distribution. Built-in program controller and instrument panel. Silicon carbide heating elements — temps. to 1350°C. Easy to maintain. Shipped complete, ready to operate. Type LA-19D furnace with nickel-chrome elements — temps. to 1000°C.

HAYES LAC-55M ALLOYING FURNACE Now used by many major electronics firms for alloying, metal bonding, soldering, other applications requiring close temp. control through 300°C to 1100°C. Unusual flexibility. 5-zone temp. control . . . maintain temps. within ±½°C.



HAYES MS-31R RECIRCULATING DRYER Molecu-Dryer complete with gas/air recirculating unit, for "dry box" atmospheres for assembly of transistors diodes, other electronic parts. Dew points to –100°F or lower, Economical — replaces expensive tank nitrogen. Simple controls. Easy maintenance. Standard units caps. to 16,000 CFH. Higher caps. on special order.

Hayes equipment covers every electronics requirement: zone refining, crystal growing, alloying, metal bonding, glass (or ceramic)-to-metal sealing, vacuum heat treating, high temp. outgassing, air/gas drying, atmosphere generation (hydrogen, nitrogen, dissociated ammonia, forming gas, endo and exo gases.) With theoretical development work in the lab backed-up by a double-check on actual production-scale equipment . . . Hayes can help you improve quality, cut costs, increase production. Write for Bulletin 5711C.

C. I. HAYES, INC.

847 WELLINGTON AVE., CRANSTON 10, R.I.

Established 1905

ELECTRIC FURNACES

It pays to see Hayes for metallurgical guidance, lab. facilities, furnaces, atmosphere generators, gas and liquid dryers, pHayes-Master (TM) control units.

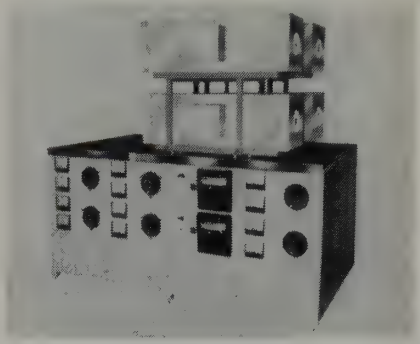
Circle No. 36 on Reader Service Card

cific Semiconductors, Inc. They combine the high voltage and high forward conductance characteristics of the 1N645 series with the low leakage characteristics of the 1N457 series. Leakage is an order of magnitude better than the 1N645-1N649 and significantly lower than the 1N457-1N459 at 25°C. At 150°C the new types have the same leakage as the 1N645 series at 100°C.

Circle 119 on Reader Service Card

Diffusion Furnace

A new diffusion furnace, Model DF-3, has been developed by Electroglas, Inc., which can handle over 1000 wafers at one

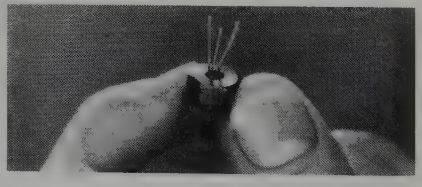


time. One of the variables in producing uniform diffusions is eliminated by the precise temperature control attainable with this furnace. The flat zone is at least 12" long and can be maintained at a temperature of 1200°C with a variation of not more than ±2.0° C. Maximum operating temperature is 1300° C.

Circle 166 on Reader Service Card

Heat Sinks

Heat sinks for mesa/planar transistors in the TO-18 package are available from the Thermolloy Company. This new configuration lets the designer use heat sinks only as he needs them. Ratings approaching 25°C case temperature are being



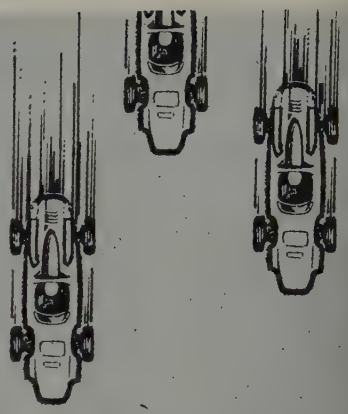
achieved because the units give positive contact as opposed to a conventional "press fit." Contact is obtained by a threaded nut which securely grips both sides of the transistor weld flange, the point of maximum heat. Heat generated in the transistor is then conducted directly through the threaded nut to the chassis.

Circle 139 on Reader Service Card

Welding Accessories

Keyed particularly to the needs of production-line component packaging is a new line of precision welding accessories developed for use with Weldmatic Model 1032 Miniature Welding Head and other equipment. Advantages of specialized accessories include reduced eyestrain and operator fatigue, clear and uncluttered working area, and increased reliability of production modules.

Circle 108 on Reader Service Card



LAPPING

The starter drops his checkered flag, and the super-charged engines of the racing cars roar in unison as the drivers spurt ahead.

Out leading the pack is the Semiconductor Specialties **Special**, a new entry in the semiconductor materials processing service field. With a pit crew thoroughly experienced in materials processing and device engineering, and with processing pioneer Bob Tucker at the wheel, the **S.S. Special** has taken the lead in this high-speed competition for superiority in precision processing.

They call it **lapping the field** when the leader passes the other cars a second time. The **S.S. Special** has lapped the field in lapping — as well as the other precision processing services.

The **S.S. Special** is built to stay out in front, by providing fast, highly accurate processing. Watch our smoke.

Whoosh!

slicing, lapping, etching, dicing, sizing, special shapes.

SEMICONDUCTOR SPECIALTIES CORP.

252 Garibaldi Ave., Lodi, N. J.
PRescott 3-6933

Circle No. 37 on Reader Service Card

Heat Sink

Owen Laboratories Semiconductor Heat Sink is designed for use at the breadboard stage of solid state circuit design. It will hold most types of power transistors, rectifiers, and SCRs, including those in the diamond-shaped TO-3 case,

the TO-36 and similar round cases, and types having 8-32, 10-32, and ¼"-28 mounting studs on non-terminal faces. Additional space is provided for new semiconductor case configurations which may be introduced in the future.

Circle 128 on Reader Service Card

Metalized Ceramic Bases

High temperature metalized ceramic bases suitable to 1000° C, used for mounting electronic components such as resistors, diodes, transistors, and capacitors are available from Metalizing Industries, Inc. The bases use alumina ceramics ranging in purity from 85% to 96%, with a high temperature metal coating, nickel

plated to permit the user to silver braze or soft solder the closure. The company offers a range of parts custom fabricated to customer's prints.

Circle 116 on Reader Service Card

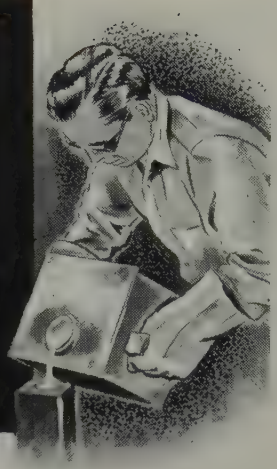
High Forward Conductance Diode

A new silicon computer diode, the Delta DW 120, features 4 nanosecond reverse recovery and 400 ma forward current @ 1V. Designed by Delta Semiconductors to meet the high specifications required in ultra fast computer logic circuits, the parameters also include 100 V minimum peak inverse voltage and .025 ua maximum reverse current @ 75V. A companion diode, the DW 130, features

METALS

For Use in the

SEMI-CONDUCTOR FIELD

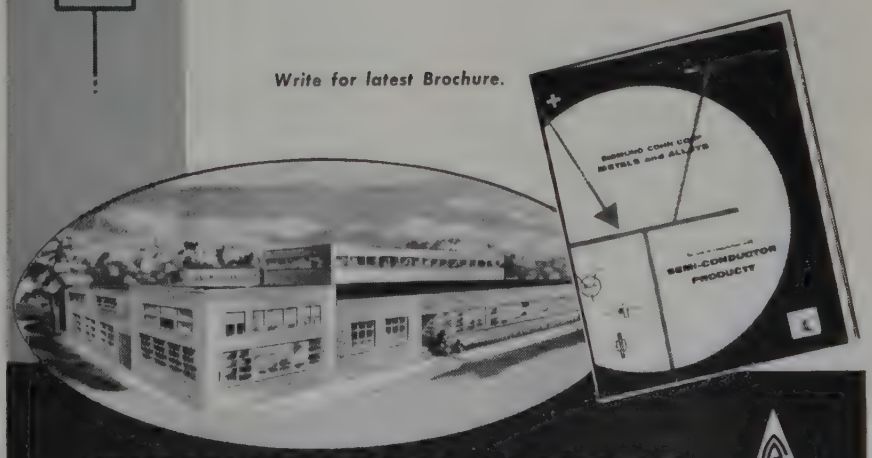


SINCE 1901, this organization has specialized in the development and manufacture of precious metal products...We are in an excellent position to serve the Semi-Conductor industry with Gold, Platinum, other metals and alloys.

PLATINUM and PLATINUM-RHODIUM for Thermocouples

Among the metals we supply are high purity Platinum and Platinum-Rhodium for Thermocouple purposes...From the refining of component metals to final testing, every step is carefully checked to assure product uniformity, homogeneity and calibration. Both Platinum and Platinum-Rhodium are available in sizes as small as .001" diameter. Two grades of each can be supplied, matching N.B.S. values with a tolerance of ±.1% and ±.25% respectively. Specification sheets are available on request.

Write for latest Brochure.



SIGMUND COHN CORP.

121 SOUTH COLUMBUS AVE. MT. VERNON, N.Y.

SIGMUND COHN CORP. OF CALIFORNIA • 151C N. Maple St., Burbank, Cal.

Circle No. 38 on Reader Service Card

An important

NEW GUIDE to ELECTRONIC CHEMICALS

of high, defined purity

...may we send you your complimentary copy? Mail coupon below.

More than 40 electronic chemicals of exceptional purity appear in this handy new reference guide. You will find, for example, high purity 'Baker Analyzed' Reagents for semi-conductors...vacuum tubes...ferrites...thermistors.

Do you know that every 'Baker Analyzed' Reagent electronic chemical is labeled with an *Actual Lot Analysis* that defines the degree of purity to the decimal? And that many are labeled with an *Actual Lot Assay* as still a further proof of purity? Do you know that in many of these chemicals copper, nickel and other critical impurities are defined at levels of .1 and .2 parts per million? And that several important solvents are now controlled to meet *stringent resistivity specifications?*

SEND FOR YOUR FREE GUIDE TODAY.

It lists J. T. Baker electronic chemicals controlled to extremely low limits of critical impurities, and includes specification sheets that prove the superiority of 'Baker Analyzed' Reagents for electronic specifications. Fill in coupon now.

J.T.Baker CHEMICAL

J. T. Baker Chemical Co.
Phillipsburg, New Jersey Dept. SCP-7

Gentlemen: Please send me my copy of "J. T. Baker Electronic Chemicals."

Name_____
Title_____
Company_____
Street Address_____
City_____ Zone____ State_____

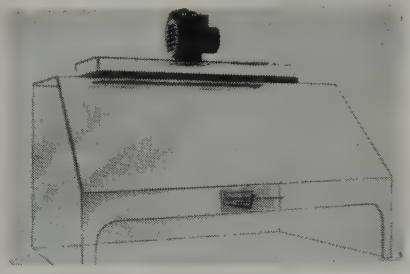
Circle No. 39 on Reader Service Card

identical parameters, with the exception of 50 ma minimum forward current @ 1V and the low capacity of 4 pico farads at 0V. Both are "Cool Junction" types with a special alloy-diffused junction and a big 600 MW heat sink for maximum heat dissipation.

Circle 125 on Reader Service Card

Dust Free Hood

Ray Products, Inc., has introduced the Micron-Aire, a new line of Dust Free Hoods. Units, featuring improved filter and improved design, are available in Plexiglas or metal. Both models are



equipped with a new, high efficiency submicron, disposable filter NBS tested for arrestance of air contaminants as small as 0.01 microns. A quiet, squirrel-cage, continuous duty blower with 140 CFM output provides positive pressure to prevent room air from entering cabinet. Operates on 115 volts, 60 cycles, single phase 130 watts.

Circle 120 on Reader Service Card

Transistor Heat Dissipators

Transistor heat dissipators available for a variety of sizes and types of power diodes and transistors have been announced by U. S. Heat Sink. They utilize the principle of radial cooling fins for heat dissipation, are fabricated from one piece aluminum bar stock and contain

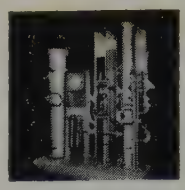
no welded or brazed joints that would serve as a barrier to thermal transfer. Their small size allows them to be mounted integrally on boards with other electronic components. The large heat dissipating area eliminates the necessity of mounting transistors or diodes on separate or isolated plates.

Circle 123 on Reader Service Card

Silicon Diode

Dickson Electronics Corporation introduces a new 50 watt silicon diffused-junction Zener diode in a DO-5 11/16" stud package. Carrying EIA type numbers 1N3305B through 1N3340B, thte new units cover the 6.8 through 100 volt range

Demineralizing Equipment **NEWS** from Penfield



Fully "Packaged" System Supplies 125-150 GPH of 18 Megohm Water

Penfield's new S-150 Demineralizing System includes multiple influent filters to remove turbidity, master dual-column demineralizer, scavenging carbon filter, polishing mono-column demineralizer, sub-micron effluent filter — all completely "packaged" on a single skid, ready to deliver an effluent of 18 megohms and better upon simple connection to service lines. (Other fully "packaged" Penfield systems available with capacities from 60 to 10,000 GPH.)

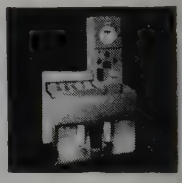
Pressure-Type Demineralizer "Polishes" to Ultra-High Purity at Point-of-Use

The Penfield PM-8 Demineralizer supplies up to 50 GPH of 18-22 megohm water — is ideal for point-of-use "polishing." Permanent cartridge design prevents raw water by-pass experienced with "canned" resin units. Cartridge unscrews by hand to permit easy resin renewal from bulk supplies, enabling substantial savings in replacement resin costs. Unit also can be charged for use as a cation exchanger, anion exchanger, carbon filter, oxygen or organic remover, and is adaptable for scavenging oil from gases.

In-Plant Regeneration Unit Saves 90% of Costs of Demineralized Water

A Penfield Regeneration Unit makes the renewal of exhausted resins from Point-of-Use Demineralizers an easy in-plant function. Operator merely feeds resin into unit, then turns a single master switch to control resin separation, regeneration, rinsing and proper re-mixing. Average operating cost, including all labor and regenerants, is less than 30c per cartridge.

Fully Integrated Weir Washer "Polishes," Heats, Monitors, Cascading Water



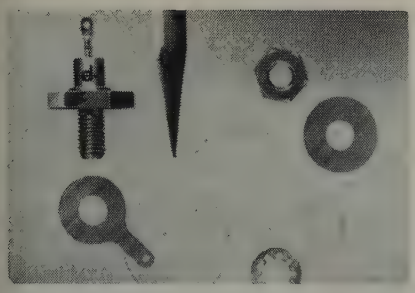
Integral filters and pressure-type demineralizers enable circulation of 18-22 megohm water through multiple partitioned tank of a special weir design that precludes stagnation. Direct reading conductivity meter permits instant monitoring at any of three check points. Novel clip bar makes replacing heat elements simple. (Penfield also constructs weir washer tanks in standard sizes or to customer specifications, using a wide variety of materials such as block tin, cast acrylic plastic, etc.)

15 years of ion exchange pioneering means that Penfield has on file field-proved answers to most industrial water problems — usually can detail the system you need by phone, ship your completely "packaged" units in a matter of days. Try a phone call or letter and see for yourself.

Penfield Manufacturing Co., Inc.
Telephone: BEverly 5-1694
19C High School Ave., Meriden, Conn.

Serving the Electronics Industry with Ion Exchange Systems • Filters • Weir Washers • Parts Baskets

Circle No. 40 on Reader Service Card

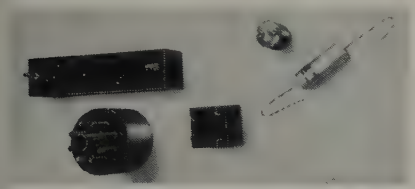


and have a standard tolerance of 5%. Tolerances of 10% and 20% are also available, as are units having a reverse polarity. Cases are hermetically sealed with junctions isolated from deleterious ambients by very rugged, resistance-welded, glass-to-metal seals. External surfaces are corrosion resistant.

Circle 132 on Reader Service Card

High Voltage Potted Rectifiers

Solitron Devices, Inc., announces the development of a line of double diffused silicon high voltage potted rectifier assemblies rated up to 50,000 peak reverse volts and 1 amp d-c per block. Called

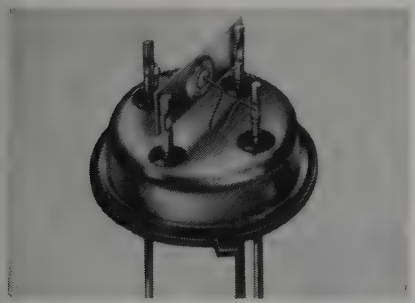


the SDI Series Solidpaks, the assemblies are available in the widest range of configurations. There are over 1,000 standard sizes to choose from. Units are designed in single phase (half wave, center tap or full wave) and three phase (half wave, full wave or star), or in protective networks and tube replacements. Operating and storage temperature range is 65°C to 150°C.

Circle 135 on Reader Service Card

Transistor Series

Silicon Alloy Transistors, 2N923 series and 2N2002 series, are currently being marketed by National Semiconductor Corporation. Available in the compact TO-18 package, feature high betas and high breakdown voltages, they are designed to replace several TO-5 transistors including 2N1440 & 41, 2N327A & 8A, 2N1228 thru 2N1233. Designed for use in low level, audio, servo, and DC ampli-



fiers, the 2N923 series offers specific parameter features for each unit. The 2N924 features a beta of 24-70; 2N927 & 8 have BV_{EBO} of −80 and BV_{CEO} of −70. All units have maximum rated leakage currents of 25nA.

Circle 138 on Reader Service Card

NEW from TI

CRYSTAL RESISTIVITY METER

Measures bulk or slice material

Adaptable for use with other probes

Compact and portable

Texas Instruments new, fully-transistorized Model 635 Crystal ρ Meter is the first portable, a-c instrument designed to measure both bulk and slice resistivity of semiconductor crystals. More accurate and stable readings are achieved by reducing the effect of noise and stray pick-up.

The TI Crystal Resistivity Meter uses a 1000-cycle, square-wave, constant-current source with superimposed d-c bias on probe points to reduce point contact resistance. Ten ranges, selectable by front panel range switch, measure resistivities from .01 to 300 ohm-centimeters, full-scale.

A slice adapter measures resistivity of slices from .007 to .037 inch in thickness. Precision jeweled TI probes are available for measurements of germanium or silicon. The meter can be calibrated for use with other probes having contact spacings from .030 to .080 inch.

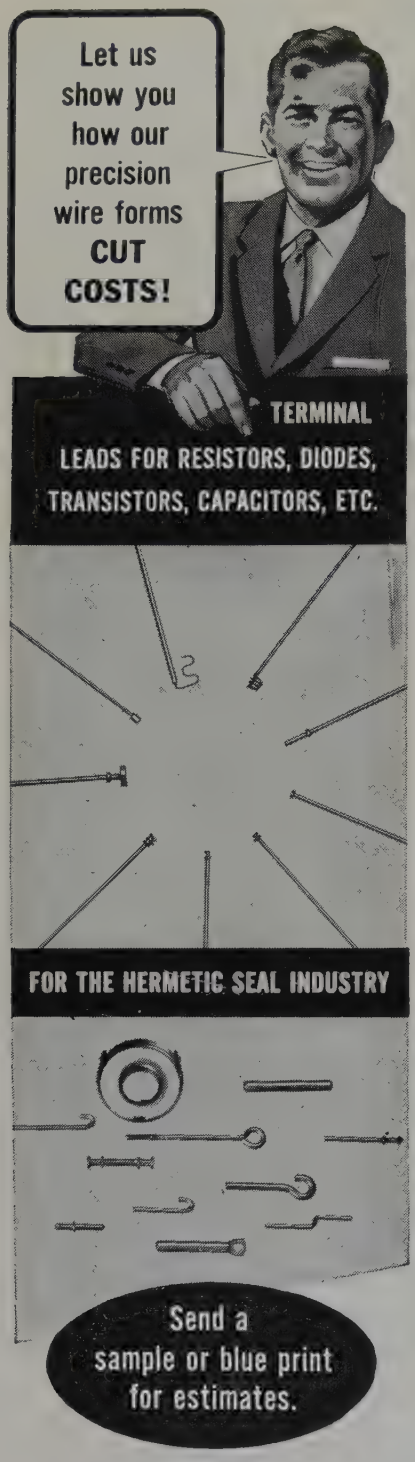
Write for complete information.

APPARATUS DIVISION
PLANTS IN HOUSTON
AND DALLAS, TEXAS

TEXAS INSTRUMENTS
INCORPORATED
3609 BUFFALO SPEEDWAY
P. O. BOX 6027 HOUSTON 6, TEXAS

436

Circle No. 41 on Reader Service Card


Let us show you how our precision wire forms CUT COSTS!
TERMINAL LEADS FOR RESISTORS, DIODES, TRANSISTORS, CAPACITORS, ETC.
FOR THE HERMETIC SEAL INDUSTRY
Send a sample or blue print for estimates.

When Art Wire tackles the job, big gains in precision and uniformity are possible on small components . . . resulting in big savings in time and production costs. In addition, Art Wire's modern production methods produce a wide variety of components more economically.

Art Wire specializes in wire forms designed for today's automatic production lines . . . manufactured to assure the economy of an uninterrupted work flow.

ART WIRE AND STAMPING CO.

29 Boyden Place, Newark, N.J.

Circle No. 42 on Reader Service Card

Book Reviews

TITLE: Resistance and Resistors

AUTHOR: Charles L. Wellard

PUBLISHER: McGraw-Hill, New York

Resistance and Resistors is a veritable textbook on the stated subject. It is remarkable to note, that although the resistor is the most used of all components, there is really very little collected information on the use, construction, rating and reliability of these devices. This book aptly fulfils the need.

The first part of the book considers aspects of resistance. There are chapters on resistance theory, materials and measurement techniques. The chapter on resistance and reliability (Chapter VII) is a typical example of the excellent presentation and well organized approach. This chapter considers economics, choice and application. Material discussing reliability studies is carefully tied to well-marked graphs of predicted failure rates of both the resistors and equipment. The material is referenced to a well-compiled bibliography.

The second part of the book deals chiefly with type of resistors. Every conceivable type of commercially available resistor is carefully described. JAN ratings are discussed, derating curves are supplied, tabulated specifications and RF performance are carefully detailed. Wire wound, carbon, high precision, high voltage, low medium and high power resistors are all carefully analyzed. Various topics of special interest are covered. There are chapters on thermistors, audio attenuators, printed circuit resistors and precision Pyrolytic-film types. As in the first part, all of the text is well illustrated with much use made of standard charts and previously published material.

Resistance and Resistors is an excellent text. It certainly will provide a ready reference to resistor and resistance characteristics and should be especially valuable to designers concerned with high reliability or wide environmental range performance.

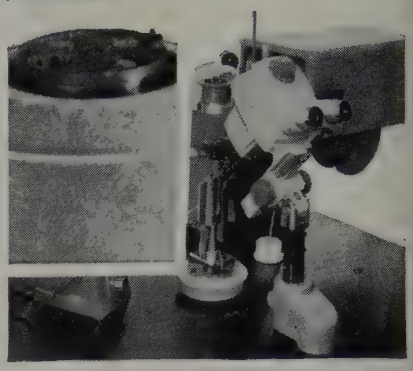
TITLE: Analytical Chemistry of Titanium Metals and Compounds

AUTHOR: Maurice Codell

PUBLISHER: Interscience Publishers, New York.

Titanium has found many uses in recent years in the missile and semiconductor fields. *Analytical Chemistry of Titanium Metals and Compounds* is

K&S NEWS



WIRE BONDER — Indexing heat column (inset) doubles output of this Nail Head (Ball) Bonder for attaching fine wire to stripes on semiconductor devices.

K&S MODEL 444

for precision ball-bonding of fine wires to headers

Inherent design of this precision equipment cuts time and cost, gives high output in positioning and bonding of ultra-fine wire to stripes on semiconductor devices.

- K&S chessman joy-stick micropositioner with accuracy of 10 to 15 millionths of an inch; plus ease of gross positioning over header
- Automatic sequencing of header-holding heat columns which preheat one header to positively controlled temperature while bond is made on other header
- Precision automatic wire feed
- Entire operation under constant visual control (B&L Stereo-Zoom microscope optional) and protected by cover of forming gas

For additional information about K&S equipment — including probes, scribers, dice mounters, wire bonders, micropositioners and microcircuit machines — *write or call . . .*

KULICKE and SOFFA
MANUFACTURING CO. INC.

Pioneer Designers and Builders of Equipment for the Semiconductor and Microcircuit Industries

401 NORTH BROAD ST.
PHILADELPHIA 8, PA.
WAlnut 5-4270
Direct Distance Dial Code: 215

Circle No. 43 on Reader Service Card

Volume IX of a series on Chemical Analysis. This book is concerned chiefly with providing the necessary information for chemists to analyze any titanium-containing compound or material.

The book is divided into four sections which include procedures necessary to isolate and analyze titanium from titanium-rich materials. Spectroscope, vacuum line and solution are the methods covered in excellent detail.

Part II of the book describes the details of the separation of specific metallic elements from various titanium materials. Each of the ten chapters in this section considers one element. The various procedures that can be used are covered in great detail and many different methods are described.

The third part of the book completes the separation methods by describing the separation from titanium of non-metallic elements such as oxygen, sulphur, boron, etc. Again a chapter is devoted to each element grouping and the material is well detailed.

The fourth section covers the analytical methods for titanium dioxide pigments, titanium tetrochloride. The same analytical procedures are utilized to describe the processes in detail.

Analytical Chemistry of Titanium Metals and Compounds is an excellent chemical text book. It is concerned mainly with laboratory procedures, however the well described methods and techniques will aid in undertsanding titanium compound and material composition.

By Stephen E. Lipsky

Application Notes
(from page 41)

onds. The change in temperature will be

$$\Delta T = P_{Z\,max}\,\theta_{JC}\left[\frac{1 - e^{-t_1/RC}}{1 - e^{-t/RC}}\right] \quad (9)$$

where

t_1 = "on" time = 10 milliseconds, and
t = "on" + "off" time = period = 25 milliseconds.

Using a 30-volt, 50-watt zener in conjunction with the thermal breaker, the maximum change in temperature from Equation 9 is

$$\Delta T = \frac{1380}{R_S}.$$

This ΔT is approximately one-half the temperature rise which occurred in Equation 6. Thus, one-half as many zeners could be used.

The circuit shown in *Fig. 70.5* will protect AC-operated equipment. Each zener shown may be a stack of several lower voltage units if the thermal load has to be spread out. The 200 volts is arbitrary and could be greater if the equipment can carry it, but it should not be much less or the zeners could remain in the fired condition when the steady-state voltage is high.

THE S. S. White Industrial Airbrasive® Unit

There may be easier ways to tap junior's piggy bank...but none that could craftily slice a piece out of a fragile ceramic part the way Industrial Airbrasive can.

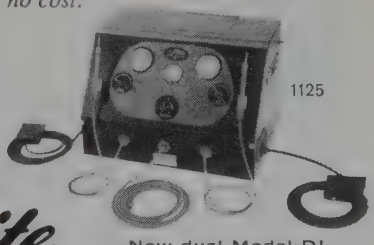
The secret of the Airbrasive's ability to cut hard, brittle materials is its accurate stream of gas-propelled abrasive. The cutting action is cool and completely shockless. Highly flexible in use, the same tool will make a cut as fine as 0.003" or it will frost, abrade or clean a large area.

Every day new uses are being found for the Airbrasive in production lines and in the laboratory . . . deburring small parts . . . shaping, drilling or cleaning germanium and other crystals . . . wirestripping potentiometers . . . removing fine films . . . printed circuits . . . micromodules . . . and many others!

Important too; the cost is low . . . for under $1,000 you can set up your own Airbrasive cutting unit!

Send us your most difficult samples and we will test them for you at no cost.

SEND FOR
BULLETIN 6006
. . . complete information.



New dual Model D!

WESCON
Booth 5128

S. S. White

S. S. White Industrial Division Dept. 31A, 10 East 40th Street, New York 16, N. Y.

Circle No. 44 on Reader Service Card

PURE CARBON

HI-PURITY... HARD-DENSE CARBON and GRAPHITE for

1. **GLASSING BOATS**
2. **ALLOYING BOATS**
3. **CRUCIBLES**
4. **EMITTER and COLLECTOR WASHERS**

- *PROVIDES OUTSTANDING OVEN LIFE*
- *RESISTS OXIDATION AND MECHANICAL EROSION*

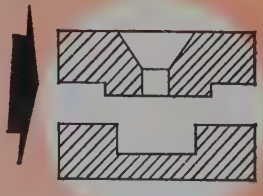
The Pure Carbon Company has complete facilities for the precision manufacturing of all types of boats and fixtures in *Grade L-56 and other outstanding materials. We have also pioneered the manufacture of small, extremely accurate emitter and collector washers, header weights, etc., in **Grade P-1.

*The most widely used electro-graphite in the semi-conductor industry

**Molded-to-size carbon graphite with dense, smooth surfaces and chip-free edges

EMITTER and COLLECTOR WASHERS

Sectional view of typical configuration shown 20X size



Write for complete information and quotations

PURE CARBON COMPANY, INC.

449 HALL AVE. ST. MARYS, PENNSYLVANIA

Circle No. 45 on Reader Service Card

New Literature

Monsanto Chemical Company has announced that it is now making available a manual describing evaluation procedures for use on gallium arsenide. The manual gives detailed methods for measurement of Hall coefficient and resistivity as well as a procedure for the measurement of dislocation density. In addition to techniques used, a complete list of equipment needed is given.

Circle 175 on Reader Service Card

General Electric Company has published a new, 6-page specification sheet on its 2N396A p-n-p germanium alloy transistor. Included are three pages of charts which show the typical base, emitter and collector characteristics of the device under varying conditions of temperature, current and voltage. In addition, two pages are devoted to the transistor's charge control switching specification.

Circle 176 on Reader Service Card

A 12-page full-color brochure which describes in detail the technology of the planar process, whereby semiconductor devices have as their major feature a surface junction protective oxide, has been issued by Fairchild Semiconductor. The brochure deals with the reliability, performance, cost and adaptability of planar devices and gives technical information dealing with performance parameters and electrical specifications and offers a planar/mesa performance comparison.

Circle 177 on Reader Service Card

Lindberg Engineering Company has issued a new four-page bulletin describing in detail gaseous and solid diffusion furnaces as an aid for basic research, pilot-plant studies and the production of semiconductors. The bulletin illustrates and describes eight different units covering the needs of all three "industries." Also included are detailed specifications of all 32 available units.

Circle 178 on Reader Service Card

The physical properties of aluminum-indium alloys for semiconductor devices are described in a series of new technical data sheets released by Alpha Metals, Inc. Each of these "Semiconductor Materials Data Sheets" contains a phase diagram of a particular alloy, a thorough description of its phase relationship and crystal structure, alloy properties and fabrication possibilities. The sheets are punched to fit a variety of binder styles.

Circle 179 on Reader Service Card

Semi-Alloys, Inc., offers a comprehensive listing of specially clad metals for semiconductor use. It includes such combinations as Gold-Indium clad Kovar clad Gold and Lead-Tin-Antimony-Germanium clad Nickel.

Circle 180 on Reader Service Card

4-page pamphlet gives a detailed presentation of Tektronix C-12 Camera that offers convenience in undistorted viewing and direct recording of oscilloscope traces. The pamphlet illustrates various

features, shows typical waveforms recorded, and lists accessories.

Circle 181 on Reader Service Card

A reference Table for Engineers and other Executives in Wall Chart form has been published by Precision Equipment Co. This Conversion Chart is useful for engineers, shop men and other executives. Included are common conversions such as inches to centimeters or watts to H. P. as well as many conversions that are difficult to locate in reference manuals. (Some such examples are atmospheres to Kgs/sq. cm, cm/sec to miles/hr, cu. ft. to liters, microns to meters, etc.)

Circle 182 on Reader Service Card

Technical Bulletin M-103, a 2-page data sheet describing their ceramic diode closure, is now available from Metalizing Industries, Inc. Lists complete specifications as well as numerous advantages, and illustrates the closure both in cross-section as well as finished parts.

Circle 183 on Reader Service Card

Cobehn, Inc., developers of new spray-cleaning solvents and methods for critical cleaning, offers a new catalog describing their products and systems. Specially engineered for cleaning small parts where microscopic cleanliness is demanded, the Cobehn system has found extensive use in precision ball bearings, jewel bearings, contact points, soldered connections, and small electronic components such as semiconductors, potentiometers, capacitors, etc.

Circle 184 on Reader Service Card

A new bulletin listing the optical as well as the physical test instruments manufactured by Gardner Laboratory, Inc., and a new general catalog which will list a complete line of their instruments and apparatus are available upon request.

Circle 185 on Reader Service Card

Microtran Co., Inc., announces the availability of a new Transformer Handbook Manual covering technical data, catalogs, pricing, and facilities and policies. The technical data has been designed to aid Component and Circuit Design Engineers in their miniaturized design and specifying transformers. Typical technical data includes Transistor Load Impedance Nomograph, Mil Designation Cross Reference, Shock, Vibration and Environmental Information, Transformer Specification Guide, Cross Reference Index, Terminal Connection Sheets, and Missile Applications.

Circle 186 on Reader Service Card

A bulletin describing the new Micron-Aire Dust Free Hoods is now available from Ray Products, Inc., The bulletin describes units featuring improved filter and improved design, available in Plexiglas or metal. Both models are equipped with a new, high efficiency, sub-micron, disposable filter NBS tested for arrestance of air contaminants as small as 0.01 microns.

Circle 187 on Reader Service Card

Owens Laboratories' eight-page handbook, written by semiconductor test circuit engineer Robert Owen, describes and illustrates the use of semiconductor test equipment in the development of solid state circuitry. Six cost-saving applications of semiconductor analyzers are detailed.

Circle 188 on Reader Service Card

QUALITY CONTROL
OF TRANSISTOR PRODUCTION MADE
EASIER, MORE EFFECTIVE

This one instrument—the Mann Type 829A Comparator—gives you new sureness and ease at several important stages of transistor quality control.

For checking photo-mask accuracy in step and repeat operations, intermediate stages of production, final checks before encapsulating. The Mann Comparator reads directly to one micron (.00004 inches) in two coordinates . . . measures with precision far beyond the capability of toolmakers' microscopes.

A special 30° eyepiece and vertical illuminator minimize operator fatigue. Convenience with accuracy and continuous measurement over a 4″x6″ area. For complete specifications, write or 'phone.

Mann Comparators are also available for other high precision applications, such as measurement of plates or films prepared at physical, chemical and biological laboratories, colleges and hospitals.

DAVID W. MANN COMPANY

A DIVISION OF GEOPHYSICS CORPORATION OF AMERICA
LINCOLN, MASSACHUSETTS—CLEARWATER 9-8015

Circle No. 46 on Reader Service Card

ULTRA DRY SEMICONDUCTOR PRODUCTION FACILITIES

Illustrated is one type of an air-tight, coved corner interior, controlled atmosphere, dry box type enclosure for the production of Semiconductors that was designed and manufactured by Kewaunee Scientific Equipment. Dew points of −75° F. (or better) can be readily maintained within the enclosures.

**The inside dope's "gone fishin'"*

For complete information, call or write →

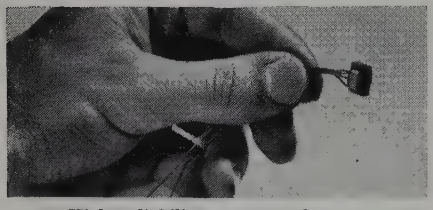
K·S·E KEWAUNEE SCIENTIFIC EQUIPMENT ADRIAN, MICHIGAN

4019 LOGAN STREET

Circle No. 47 on Reader Service Card

Super-Sub-Miniature transformers

For transistor circuitry in servo-mechanisms, hearing aids, radios, telephones



- **High reliability *guaranteed.***
- **Large quantities used, with transistors, by leading manufacturers.**
- **Some of the most Important prototypes in use today are:**

Type	H	W	D
M-200	.237	.340	.280
F-2010	.263	.410	.325
AAT-408	.307	.376	.325
SM-400	.400	.563	.485
NA-2350	.750	1	.750
GEN-2020	1 1/16"	1 1/4"	7/8"

- **Immediate delivery from inventory covering wide range of impedance ratios in sub-miniature and super-sub-miniature sizes.**
- **Prototypes—Designed or wound and enclosed to specifications. . . . Delivery within two weeks.**

For further information and catalog call or write today . . .

Frank Kessler Co., Inc., 41-45 47th St. L. I. C. 4, N. Y. • Tel.: STillwell 4-0263

Circle No. 48 on Reader Service Card

Transistorized DC Power for TUNNEL DIODE APPLICATIONS

Supplies regulated voltage output down to the millivolt region for tunnel diode biasing applications. Switchable to a constant current supply. Settable short circuit protection also makes it an ideal unit for general laboratory use.

Model	Volts	Amps	Price
T20-2	0-20	0-2	$199.50
T50-750	0-50	0-¾	199.50
*T50-1.5	0-50	0-1.5	249.50

*Constant voltage only.

SEND FOR COMPLETE CATALOG

TRYGON ELECTRONICS INC. 111 Pleasant Ave., Roosevelt, N. Y.

Circle No. 49 on Reader Service Card

Person

James G. Walton has been promoted t manager of rectifier product sales for th General Electric Company's Rectifi Components Department, Auburn, N.Y In his position, it was pointed out b W. H. Hall, manager of marketing, h will be responsible for directing an planning product sales campaigns an maintaining communications between th headquarters sales organization and th field sales office.

The appointment of Kenneth R. Osbor to the newly-created post of director c industrial development of Allied Chem ical's General Chemical Division has bee announced by Frank J. French, presi dent. In his new post, Mr. Osborn pri marily will be concerned with investi gating promising new products an expediting their commercial productio With the division 26 years, he was chie engineer for the past two years.

Pyrofuze Corp., an affiliate of Sig mund Cohn Corp., announces tha Franklyn E. Stevens, Jr. has becom associated with their organization i connection with the development c Technical Sales. Pyrofuze is a bimeta lic product (Patent No. 2,911,504) tha at 650°C alloys exothermically to crea temperatures up to 2500°C.

Richard W. Young has joined the fie engineering staff of the Sprague Elec tric Company, it was announced by Ca roll G. Killen, Vice President, Industri and Military Sales. Mr. Young will b product specialist for silicon dioxid capacitors.

The appointment of Roger A. Swanso as Pacific regional sales manager for th Semiconductor Division of Sylvan Electric Products Inc. has been an nounced by Ernest H. Ulm, divisio general marketing manager. Mr. Swan son has been transistor product sale manager since May, 1960. In his ne position, he will have his headquarte at Sylvania's sales office at Los Angele California. He succeeds William R. We who was recently named national sale manager for the division.

The appointment of J. Gordon Schontz ler as southeastern regional semicon ductor sales manager for Philco Co poration's Landsdale Division wa announced. William F. Maher, semicon ductor sales manager explained that M Schontzler will be stationed at a newl opened office located in Paramus, Ne Jersey, and be responsible for sales o Philco's transistors, tunnel diodes, an special semiconductor devices through out the southeastern states.

Seymour Harrison and Norman Milk man have joined the Trak Electronic Company, Wilton, Conn. to form a ne Data Processing Engineering Depart ment. The new department will be de voted exclusively to advanced data proc essing engineering and the developme of data display techniques.

Notes

Dr. Irvin H. Solt, Jr. has been named to head the new Microwave Physics Section of the Research and Development Laboratory of Fairchild Semiconductor Corporation, Mountain View, Calif. He will investigate the applications of semiconductor technology to microwave components, according to Dr. Gordon E. Moore, head of Research and Development.

Charles Edlund ("Chuck") Laitsch has been appointed representative of Conforming Matrix Corporation for Western and Northern Michigan. Mr. Laitsch has an extensive background in the painting of die castings, stampings and injection and vacuum molded products.

The Metals Division of National Research Corporation has appointed E. Ronald Einarsen as eastern area manager. Mr. Einarsen has established his sales office at 25 Westwood Avenue, Westwood, N. J. NRC's Metals Division produces tantalum.

Appointment of James A. Horn as manager of manufacturing for the El Monte, California facility of the Semiconductor Division of Hoffman Electronics Corporation was announced by Marvin G. Whitney, vice president and general manager of operations for the division. Mr. Horn's responsibility will cover all phases of production control, purchasing and plant maintenance.

Richard A. Campbell, Executive Vice President of Pacific Semiconductors, Inc., and Dr. Ralph P. Johnson, Vice President of Thompson Ramo Wooldridge Inc., Electronics Group, have been named members of the PSI Board of Directors, it was announced by Dr. Harper Q. North, President and Board Chairman. PSI is a subsidiary of TRW.

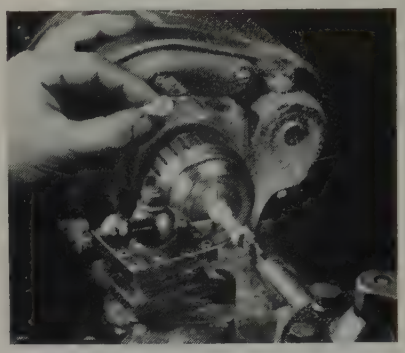
Wilford Beasley has been appointed chief engineer of The Birtcher Corporation/Industrial Division it was announced by president Cecil J Birtcher. Mr. Beasley will direct the division's engineering activities in the design of electronic cooling/retention devices and in their new field of thermoelectric cooling. He was formerly senior project engineer at Hoffman Electronics Corp.

Two new members have been appointed to the Board of Directors of Lindly & Co., Inc., Mineola, L.I. N.Y., manufacturers, designers and engineers of industrial electronic inspection and control equipment, precision photoelectric systems and optical units. They are Robert E. Burns and Chester D. Seftenberg.

The Mallory Semiconductor Company has appointed W. D. Thorn Sales Manager. Formerly a senior section engineer for that division of the company, Mr. Thorn will supervise all field sales and sales engineering for Mallory semiconductor products.

Problem: "On spec" yield of semi-conductor components drop as much as 40% within 50 cycles when using *graphite* jigs

Solution: **BORON NITRIDE** *for semi-conductor jigs*



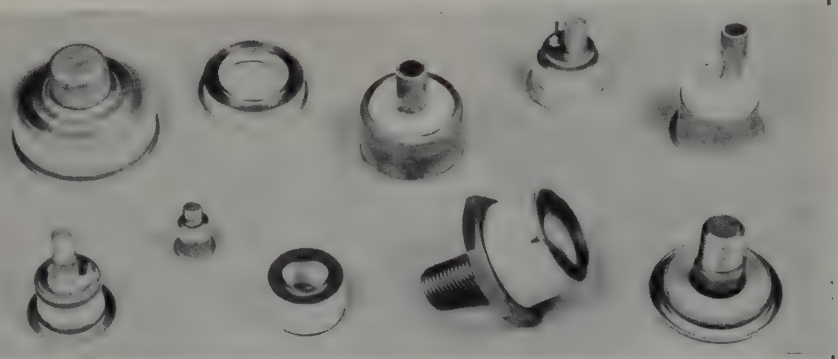
Boron nitride machines easily to close tolerances, resists chipping and retains internal jig details. It holds dimensions, has excellent release characteristics and is non-toxic.

Contact with silicon, germanium, indium, antimony, lead and other metals has little effect up to 1800 F in oxidizing or reducing atmospheres. For more information on greater yields with boron nitride, write Latrobe Plant, Refractories Div., Carborundum Co., Latrobe, Pa.

CARBORUNDUM®

Circle No. 50 on Reader Service Card

DESIGNING HIGH-CURRENT HIGH-POWER SEMICONDUCTOR RECTIFIERS?



USE ADVAC SUPER-RUGGEDIZED CERAMIC-TO-METAL HOUSINGS

CHECK THESE ADVANTAGES USING ADVAC RECTIFIER HOUSINGS:

- High Mechanical Strength, with shear strength at the metalized seal in the order of 15,000 psi.
- Superior thermal shock resistance at temperatures to 1000 deg. F compared to glass-to-metal seals.
- High vacuum seal, capable of withstanding subsequent processing at temperatures as high as 1700 deg. F . . . a truly hermetic seal compared to glass or epoxy encapsulations capable of withstanding leak tests to 1×10^{-9} cubic cm./sec.
- High dielectric combined with excellent thermal conductivity properties.
- Inorganic ceramic will not contaminate the semiconductor junction. The alumina ceramic does not decompose nor are volatiles discharged at high temperatures.
- Temperature resistance of the ceramic-to-metal construction permits continuous operation at temperatures to 1700 deg. F.

Send prints for quotation or ask for Bulletin A-100.

ADVANCED VACUUM PRODUCTS, INC.
HIGH TEMPERATURE CERAMIC-TO-METAL HERMETIC SEALS
430 FAIRFIELD AVENUE • STAMFORD, CONN. • DAvis 5-3881
SUBSIDIARY OF GLASS-TITE INDUSTRIES, INC.

Circle No. 51 on Reader Service Card

Graphite Facts

by George T. Sermon, President
United Carbon Products Co.

Purchasing Policy... and Russian Roulette!

Management policy decisions sometimes seem somewhat like Russian Roulette. For example:

"Three competitive bids will be obtained. The company submitting the lowest bid will be awarded the purchase order. Under unusual circumstances, the second lowest bidder will be chosen and a letter of explanation submitted to the president."

Sound familiar? And, in five of six purchases, this policy is as harmless as the unloaded chambers of a revolver used in Russian Roulette. However, there's always a good chance that an order placed *according to policy* can be a major disaster. Since your Purchasing Agent is human, he will feel he's doing his job best by shopping for *price*. There's the danger . . . *policy* replaces *judgment*.

I have seen this happen time and again in the rapidly growing semiconductor field. Graphite boats will be purchased because of a small price advantage (a matter of policy) without regard for: ability to deliver future orders of consistent quality; breadth of experience which could help solve or circumvent production bottle-necks; capacity to meet the future potential of your own product; financial soundness and business responsibility.

When you buy a United product, you get all of this. It's our policy.

UNITED carbon products co.

BOX 747 BAY CITY, MICHIGAN

Circle No. 52 on Reader Service Card

INDEX TO ADVERTISERS

For reference purposes, the advertisers index includes all regular advertisers who have run within the current contract year. These advertisers who appear in this issue are indicated by the page number adjacent to their listing, and are shown in a bold-face type.

Accurate Specialties Company, Incorporated
Acoustica 59
Advanced Vacuum 73
Aerotronic Associates, Incorporated
Allegheny Electronic Chemical Company
Allied Chemical Corporation General Chemical Division .. 6
Allied Radio Corporation
Alloys Unlimited Incorporated
Alloys Unlimited Chemicals, Incorporated
Alpha Metals, Incorporated
American Optical Company ... 5
Art Wire & Stamping Company 68
Avnet Corporation

Baker, J. T. Chemical Company 66
Barber-Colman Company Wheelco Industrial Instruments Division
Bay State Abrasive Products Company
Becco Chemical Division Food & Machinery & Chemical Corporation
Bell Telephone Laboratories .. 22
Birtcher Corporation, The
Blue M Electric Company
Boonton Electronics Corporation
Brady, W. H. Company
Brinkman Instruments, Incorporated
Bronwill Division of Will Corporation
BTU Engineering Corporation 16
Burke & James, Incorporated 74

Carborundum Company 73
Ceramics For Industry, Corporation
Charleston Rubber Company .. 60
Cohn, Sigmund Corporation ... 65
Composite Industrial Metals, Incorporated
Conforming Matrix Corporation
Cominco Products, Inc.
Consolidated Reactive Metals, Incorporated
Consultants Bureau

Daven Company, The— A Subsidiary of General Mills 13
Davies-Shea, Incorporated
Davison Chemical Company Division of WR Grace
Delta Design, Incorporated
Design Tool Company
Despatch Ovens Company
DI-Tran Corporation
Dow Corning Corporation 4
Duramic Products, Incorporated
Dynatran Electronics Corporation

Eagle-Picher Company, The ..... **Cover III**
Eisler Engineering Company, Incorporated
Electroglas, Inc. 17
Electro Impulse Laboratory ... 61

(Continued on page 75)

Circle No. 53 on Reader Service Card

NEW SERVICE NOW AVAILABLE

SEMICONDUCTOR PRODUCTS is making a new source of information available to all firms interested in being kept up to date on materials or equipment for producing semiconductor devices. If you wish to receive all new literature on silicon, germanium, chemicals, machinery, or other such materials, circle #99 on the reader-service card. Your name will be placed on a special list which will be forwarded to all such suppliers. As these suppliers have news available in their field, you'll be notified by them immediately. This service is restricted to firms manufacturing semiconductor devices or firms contemplating entering into production within 120 days.

NORTH HILLS'

CURRENT GOVERNOR

Model CS-111

for *Constant Current*

- Precision Current Source
- Transistor and Diode Tester

▸ High Accuracy ▸ Excellent Stability ▸ Programmable

For testing and measurement of transistors, diodes, clutches, solenoids, meters, other current sensitive devices.

- Current Range is 10μa to 500 ma with 5 decade selectors.
- Regulation and stability 0.05%
- Accuracy 1%

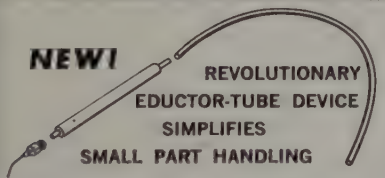
In use by leading companies for transistor avalanche test, diode PIV test, clutch testing, calibration.

Literature describing this and other constant current sources from 0.1μa to 30 amp. may be obtained from

nh NORTH HILLS
Electronics Co.
Glen Cover L. I., N.Y.

Circle No. 55 on Reader Service Card

NEW!



REVOLUTIONARY EDUCTOR-TUBE DEVICE SIMPLIFIES SMALL PART HANDLING

Unique Penfield Pickup uses 1-2 psi of air or inert nitrogen to pick up and release minute particles. Negative pressure created at hypodermic needle point is sufficient to hold germanium, silicon, other minuscule parts. To release the held particle, operator merely finger-stops an orifice in the eductor-tube. Use of Penfield Pickups eliminates all foot switches, solenoids, costly vacuum equipment, troublesome plugging problems. Send for trial sample ($10.75 each, Postage Paid) and see for yourself.

Penfield Manufacturing Co., Inc.
Telephone: BEverly 5-1694
19Y High School Ave., Meriden, Conn.

Serving the Electronics Industry with Ion Exchange Systems • Filters • Weir Washers • Parts Baskets

Circle No. 56 on Reader Service Card

BACK ISSUES

1.00 Each

1958—Jan/Feb; March/April; May/June; Nov/Dec.

1959—Dec.

1960—March, May, June, July, Aug., Sept., Nov.

1961—Feb., Mar., April, May, June, July

SEMICONDUCTOR PRODUCTS

Back Issue Dept.

300 W. 43 St. New York, N. Y.

INDEX TO ADVERTISERS

(Continued)

Electronic Metals and Electronic Research Associates Alloys, Inc.
Elinex 60
Engelhard Industries, Incorporated
Epoxy Products
Espey Manufacturing & Electronics Corporation Saratoga Semiconductor Division

Federated Electronics, Incorporated
Fisher Scientific Company

Garner, T. H., Company 62
General Electric Company Lampglass Division Semiconductor Products Department
General Instruments Corporation
Glass-Tite Industries, Incorporated
Grace Electronic Chemicals, Incorporated
Graphic Systems
Greibach Instruments Corporation

Harvey Radio Company, Incorporated
Hayes, C. I. Incorporated 64
Hevi-Duty Electric Company
Hughes Aircraft & Company
Hunter Tools Company

Indium Corporation of America, The
Induction Heating
Industrial Instruments, Incorporated
International Business Machines

Jelrus Technical Products Corporation
Johnson & Hoffman Manufacturing Corporation 59

Kahle Engineering Company ... 20
Kanthal Corporation, The
Kewaunee Scientific Equipment . 72
Kessler, Frank Company, Incorporated 72
Knapic Electro-Physics, Incorporation
Kulicke & Soffa Manufacturing Company, The 68

L & R Manufacturing Company
Lafayette Radio 76
Lepel High Frequency Laboratories 75
Lindberg Engineering Company . 10

Mallinckrodt, Industrial Chemical Division
Mann, David W., Company, A Division of Geophysics Corporation of America 71
Manufacturers Engineering & Equipment Corporation
Marshall Products Company
Merck & Company, Incorporated Electronic Chemicals Division 1
Micromech Manufacturing Corporation 9
Milgray ..... Cover IIA-IIB
Monsanto Chemical Company .. 11

(Continued on page 76)

LepeL

HIGH FREQUENCY *Induction* HEATING UNITS

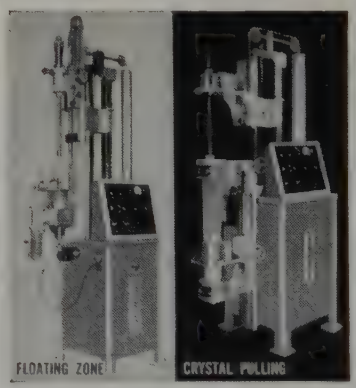
Lepel induction heating equipment is the most practical and efficient source of heat developed for numerous industrial applications

DUAL PURPOSE FLOATING ZONE AND CRYSTAL PULLING FIXTURE

A new fixture with separate attachments for crystal pulling and floating zone applications for use with a high frequency induction heating generator.

THE FLOATING ZONE METHOD is used extensively for zone refining and for growing crystals of high purity silicon for semiconductor devices by traversing a narrow molten zone along the length of the process bar in a controlled atmosphere.

THE CRYSTAL PULLING METHOD is used for growing single crystals of various materials, especially germanium, by bringing a seed of known crystal orientation into contact with the surface of the molten metal and slowly withdrawing the seed, producing progressive crystallization.



The Lepel Model HCP-D consists of the basic unit with the traverse mechanism and all the controls including the controls for the operation of the generator, and the floating zone and crystal pulling attachments. The same basic support, programming and control unit is used in either adaptation. The major variations are in the attachments and the induction coils. The change from one application to the other can be accomplished in a very short time.

Our engineers will process your work samples and return the completed job with full data and recommendations without cost or obligation.

WRITE FOR NEW LEPEL CATALOG

LepeL HIGH FREQUENCY LABORATORIES, INC.
55th ST. & 37th AVE., WOODSIDE 77, N. Y.
CHICAGO OFFICE: 6246 WEST NORTH AVE.

Circle No. 57 on Reader Service Card

THE LAFAYETTE INDUSTRIAL CONCEPT

expands your research potential through it's

Concentrated Semiconductor Coverage

Procurement speed is a major factor in todays fast moving research and development decisions. **Lafayette's "Concentrated Semiconductor Coverage"** meets these demands and pays big dividends for your research and development program in terms of increased efficiency and productivity.

Precisely what do we mean by "Concentrated Semiconductor Coverage?" Simply this, Lafayette has concentrated within its huge stocking facilities the widest, most comprehensive selection of transistors available anywhere. At only a phone call's notice, the entire lines of America's seven leading transistor manufacturers are available to you at factory low prices . . . immediate delivery to any point in the U.S. and Canada. And Lafayette's technically trained field representatives are always ready to serve you with Mil Spec. data, engineering information and application assistance. Your research program gains hours, even days, having filled its needs faster from Lafayette than any other source.

FREE! Send for the new Lafayette/Astro-Dynamics Heat Sink Guide. Matches the correct heat sink or heat sink combination with transistor package number. Use your reader service card or write: **Lafayette Radio, Dept. SP-8. 165-08 Liberty Ave., Jamaica 33, N.Y.**

Thousands of Electronic Firms Have Expanded Their Research Potential Through Lafayette. Has Yours?

LAFAYETTE
INDUSTRIAL ELECTRONICS DIVISIONS
of Lafayette Radio Electronics Corporation
"ENTERPRISE" NUMBERS IN MAJOR CITIES

JAMAICA	NEW YORK	NEWARK	BOSTON
165-08 LIBERTY AVE.	100 SIXTH AVENUE	24 CENTRAL AVE.	110 FEDERAL ST.
JAMAICA 33, N. Y.	NEW YORK 13, N. Y.	NEWARK 2, N. J.	BOSTON 10, MASS.
OLympia 8-5050	WOrth 6-5300	MArket 2-1661	HUbbard 2-7850
TWX: NY 4-933	TWX: NY 1-648		TWX: BS-447U

Circle No. 58 on Reader Service Card

INDEX TO ADVERTISERS

(Continued)

New York Air Brake Company, The Kinney Manufacturing Division
North Hills Electronics, Incorporated 75
Norton Company 19

Ohio Carbon Company
Optimized Devices, Incorporated

Penfield Manufacturing Company, Incorporated 66-75
Pereny Equipment Company, Incorporated 58
Philco Corporation Lansdale Division
Pitt Precision Products, Incorporated
Power Designs, Incorporated
Pure Carbon Company, Incorporated 70

Raytheon Company 3
General Instrument Corporation (Commercial Apparatus & Semiconductor Division)
Reid Brothers Company, Incorporated
Rescon Electronics Corporation
Research Chemical Division Nuclear Corporation of America
Research Instrument Company, Inc. 2
Ross, Milton M., Company

Schweber Electronics
Scully-Anthony Corporation—A Division of Scully Jones 58
Secon Metal Company 62
Semi-Alloys, Incorporated
Semiconductor Specialties Corporation 64
Semimetals, Incorporated 7
Sprague Electric Company Cover IV
Sylvania Electric Products, Incorporated
Chemical & Metallurgical Division
Parts Division 15

Techni-Rite Electronics, Incorporated 63
Tektronix, Incorporated .. **Cover II**
Temperature Engineering Corporation 14
Texas Instrument Incorporated 12-67
Trak Electronics Company
Division of Textool Products, Incorporated
CGS Laboratories
Trans Electronics Corporation
Tri-Metal Works, Incorporated . 8
Trinity Equipment Corporation
Trygon Electronics, Incorporated 72

United Carbon Product Company 74
Unitron Instruments Division of United Scientific Company ... 59

Vacuum Tweezer Company (The)
Veeco Vacuum Corporation

Wallson Associates, Incorporated
W. M. Welch Manufacturing
Wheelco Industrial Instruments Company
West Instrument Corporation Division
S.S. White Industrial Division .. 69

SUBSCRIPTION ORDER BLANK

→

READER SERVICE CARD

→

SUBSCRIPTION ORDER

H

	U.S.A., POSS. A.P.O., F.P.O.	ALL OTHER COUNTRIES
☐ 12 Issues	$ 6.00	☐ $10.00
☐☐ 24 Issues	10.00	☐☐ 18.00
☐☐ 36 Issues	13.00	☐☐ 25.00

☐ Remittance herewith ☐ Send Invoice

Sirs: Please enter my subscription to SEMICONDUCTOR PRODUCTS for .... issue

☐ New Subscription ☐ Renewal Subscription

PLEASE PRINT CAREFULLY—ANSWER ALL QUESTIONS

Name ..... Position .....

Company ..... Dept. .....

Address .....

City ..... Zone ... State .....

Products Mfd. .....

Please Send My Magazine to (if some other address):

Address .....

City ..... Zone ... State .....

NAME POSITION

COMPANY

STREET ADDRESS

CITY ZONE STATE

THIS READER SERVICE CARD VOID AFTER SEPT. 30, 196

All Advertisements, New Products and Literature Are Numbered for Your Convenience

SIRS: PLEASE SEND ME INFORMATION ON THE ITEMS I
YOUR AUGUST ISSUE WHICH ARE KEYED AS FOLLOWS

1	2	3	4	5	6	7	8	9	1
11	12	13	14	15	16	17	18	19	2
21	22	23	24	25	26	27	28	29	3
31	32	33	34	35	36	37	38	39	4
41	42	43	44	45	46	47	48	49	5
51	52	53	54	55	56	57	58	59	6
61	62	63	64	65	66	67	68	69	7
71	72	73	74	75	76	77	78	79	8
81	82	83	84	85	86	87	88	89	9
91	92	93	94	95	96	97	98	99	10
101	102	103	104	105	106	107	108	109	11
111	112	113	114	115	116	117	118	119	12
121	122	123	124	125	126	127	128	129	13
131	132	133	134	135	136	137	138	139	14
141	142	143	144	145	146	147	148	149	15
151	152	153	154	155	156	157	158	159	16
161	162	163	164	165	166	167	168	169	17
171	172	173	174	175	176	177	178	179	18
181	182	183	184	185	186	187	188	189	19
191	192	193	194	195	196	197	198	199	20

MY PRIMARY INTERESTS ARE .....

H

.....

.....

Postage Will Be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

FIRST CLASS PERMIT NO. 36540, NEW YORK, N. Y.

SEMICONDUCTOR PRODUCTS

300 WEST 43rd STREET

NEW YORK 36, N. Y.

Postage Will Be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

FIRST CLASS PERMIT NO. 36540, NEW YORK, N. Y.

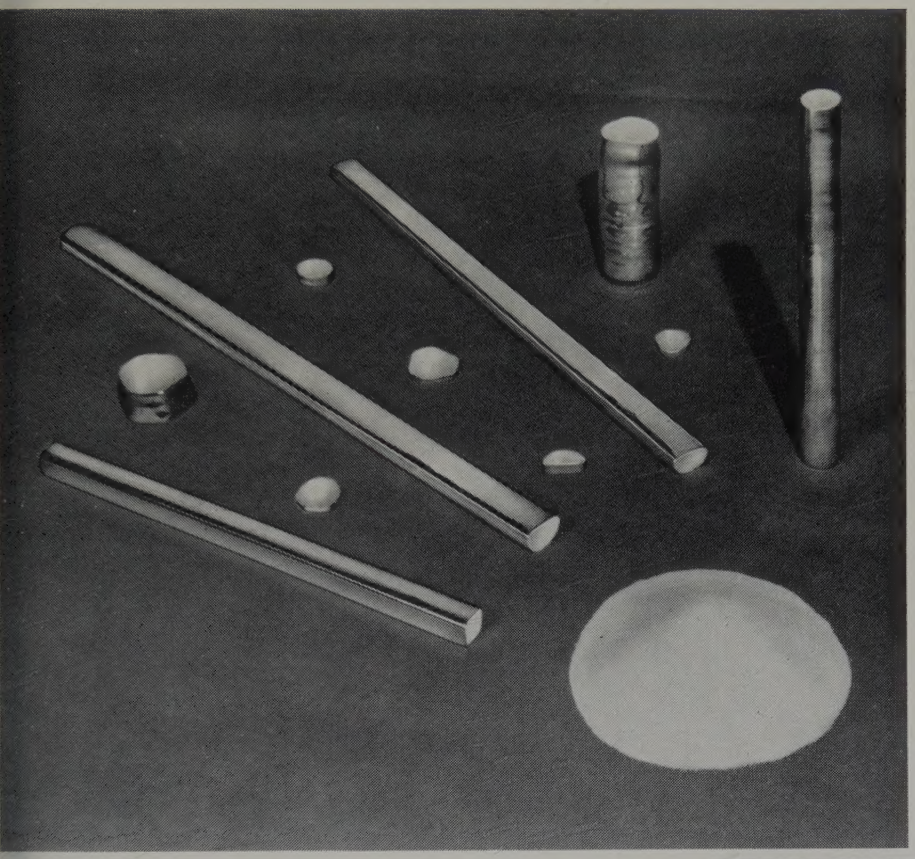
Reader Service Dep't

SEMICONDUCTOR PRODUCTS

300 WEST 43rd STREET

NEW YORK 36, N. Y.

Germanium *and other semiconductors from* **EAGLE-PICHER**



Eagle-Picher Rare Metals and Semiconductors

GERMANIUM DIOXIDE, minimum purity 99.999%.

FIRST REDUCTION GERMANIUM METAL, minimum resistivity 5 ohm-cm.

INTRINSIC GERMANIUM METAL, minimum resistivity 40 ohm-cm.

SINGLE CRYSTAL GERMANIUM [undoped] minimum resistivity 30 ohm-cm.

SINGLE CRYSTAL GERMANIUM [doped] to customers' specified resistivity.

SPECIAL SHAPES, INTRINSIC GERMANIUM METAL, for horizontal or vertical crystal growing. Wide variety in stock, other shapes furnished to customers' specifications.

SCRAP GERMANIUM PLAN, scrap Germanium may be returned for economical reprocessing under a toll arrangement.

— also immediately available

CADMIUM SULFIDE

GALLIUM, ultra pure.
Metallic crystals, minimum purity 99.9999%.
Metallic crystals, minimum purity 99.999%.

GALLIUM SESQUIOXIDE

Eagle-Picher, pioneer in Germanium, is an acknowledged leader in dependable production to meet the precise demands of the semiconductor industry. We offer a complete line of Germanium products and in addition, reprocess customers' *scrap Germanium* under our new low-cost toll arrangement.

FREE! An interesting, new brochure, "EAGLE - PICHER GERMANIUM" is now available. Write for your copy today.

EAGLE EP PICHER

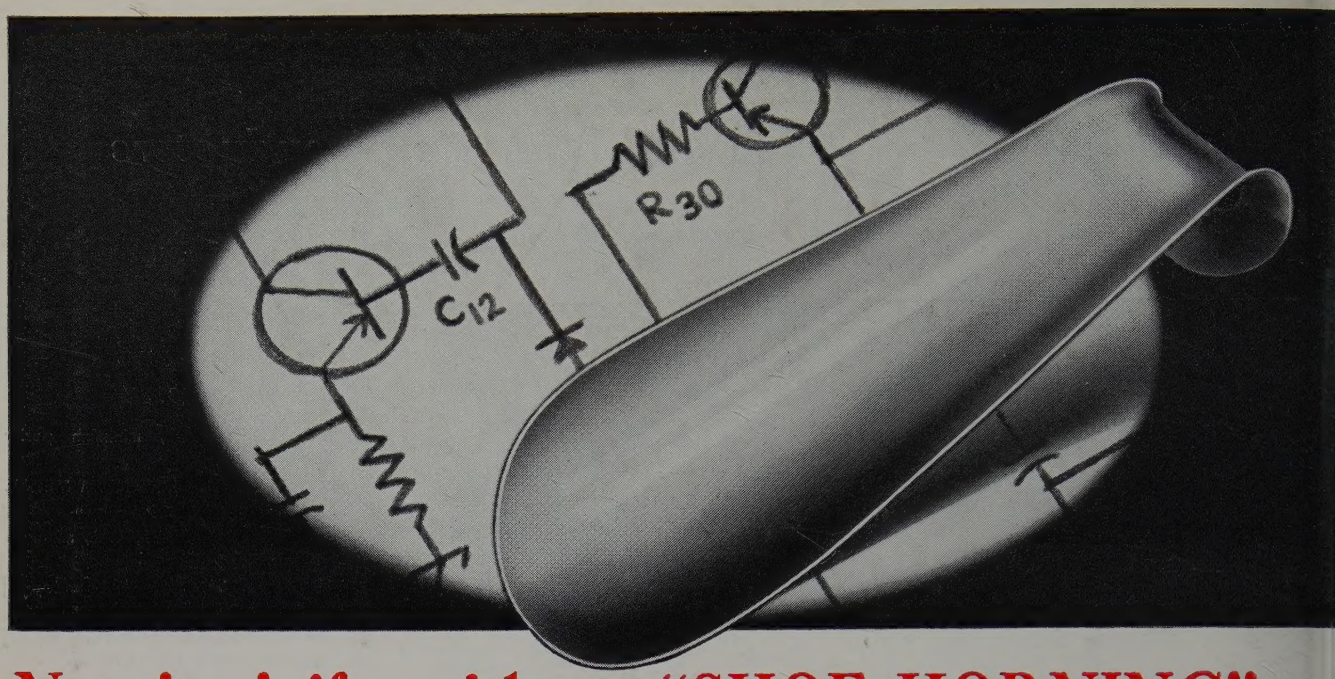
Since 1843

THE EAGLE-PICHER COMPANY

Chemical Division, Dept. SCP-861

GENERAL OFFICES: CINCINNATI 1, OHIO

Circle No. 2 on Reader Service Card



Now! minify without "SHOE-HORNING"...

TANTALEX® Solid-electrolyte Capacitors Can Help!

Big boast? No! Plain fact. You need no shoe horn to get high capacitance values into your transistorized circuits. Sprague's ultra-miniature, solid-electrolyte TANTALEX Capacitors let you minify to the hilt without sacrificing performance or reliability! This one, for example, is only ⅛" in diameter by ¼" long, yet packs a whopping 6.8 μF at 6 volts!

A Reliable Source of Supply!

Sprague Electric Company pioneered in the development of solid-electrolyte tantalum capacitors. Unmatched experience has enabled us to establish the largest production facilities in the capacitor industry. Producing more solid-electrolyte tantalum capacitors than all other suppliers combined, it stands to reason that Sprague Electric offers . . . in addition to reliability of product . . . *reliability of source of supply!*

Type 150D Capacitors can be furnished to meet all of the requirements of Military Specification MIL-C-26655A. Sprague, the pioneer in the solid tantalum capacitor field, is your first source for Types CS12 and CS13.

Polar and Non-Polar Types Available

The famous Type 150D polarized capacitor, outstanding for miniature size, excellent characteristics and reliable service life, is now joined by non-polarized Type 151D, which is useful in many new applications, such as phase-splitting in small low-voltage motors, in servo systems, in low-frequency timed circuits, in crossover networks, and in bypass applications where high ripple voltages are encountered.

● *We'll be happy to send you complete performance data covering the full range of sizes and ratings of Tantalex Capacitors. For information on Type 150D Capacitor, request Bulletin 3520D. For data on Type 151D Capacitors, specify Engineering Bulletin 3521. Address Technical Literature Section, Sprague Electric Company, 467 Marshall Street, North Adams, Massachusetts.*

You can get off-the-shelf delivery of Type 150D capacitors at factory prices on pilot quantities up to 499 pieces from your local Sprague Industrial Distributor

SPRAGUE COMPONENTS

CAPACITORS	INTERFERENCE FILTERS	HIGH TEMPERATURE MAGNET WIRE
RESISTORS	PULSE TRANSFORMERS	CERAMIC-BASE PRINTED NETWORKS
MAGNETIC COMPONENTS	PIEZOELECTRIC CERAMICS	PACKAGED COMPONENT ASSEMBLIES
TRANSISTORS	PULSE-FORMING NETWORKS	FUNCTIONAL DIGITAL CIRCUITS

SPRAGUE®
THE MARK OF RELIABILITY

'Sprague' and '②' are registered trademarks of the Sprague Electric

Circle No. 3 on Reader Service Card